FORRY (S.)

METEOROLOGY:

COMPRISING A DESCRIPTION OF

THE ATMOSPHERE AND ITS PHENOMENA,

THE LAWS OF CLIMATE IN GENERAL,

AND ESPECIALLY THE

CLIMATIC FEATURES PECULIAR TO THE REGION OF THE UNITED STATES;

WITH SOME REMARKS UPON THE

CLIMATES OF THE ANCIENT WORLD,

AS BASED ON FOSSIL GEOLOGY.

BY SAMUEL FORRY, M.D.,

AUTHOR OF "THE CLIMATE OF THE UNITED STATES AND ITS ENDEMIC INFLUENCES," ETC.

WITH THIRTEEN ILLUSTRATIONS.

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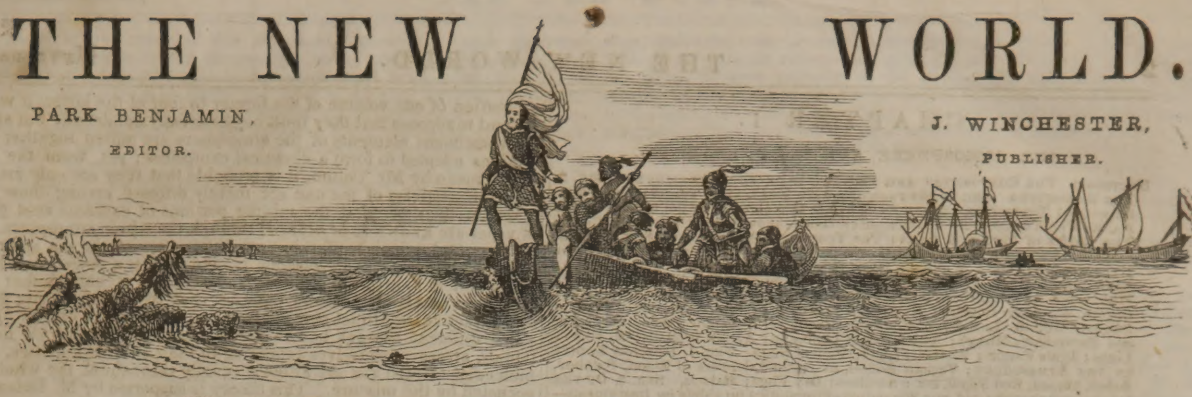

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INTRODUCTION.

This beautiful Department of Science makes us acquainted with the natural history of the atmosphere and all its properties and relations.

So closely identified is this science with the every-day occurrences of life, that man is by nature a meteorologist. The shepherd and the mariner, in ages remote, when philosophy had not yet asserted its noble prerogative of releasing the mind from the bondage of superstition, were wont to look with awe upon the face of heaven as an index to prognosticate future results from present appearances, and to read upon it "times and seasons." To Aristotle is due the credit of having first treated this subject systematically. Constantly employed in observing and comparing natural objects, he assigned the cause of the rainbow and the halo, and described minutely the various appearances of clouds, rain, hail, snow, meteors, and other atmospheric phenomena. Among the Romans, Pliny, Virgil, and Seneca, give us abundant meteorological observations, confounded with much that is absurd and fabulous. From the latter period to the revival of letters in Europe, meteorological science slumbered in oblivion; and it was not till the middle of the last century that men of genius again directed their energies to the investigation of aërial phenomena. No longer confined to the mere observance of casual atmospheric appearances, meteorology soon became, in the rapid advancement of human knowledge, a new and extensive branch of natural philosophy, comprising nearly the whole circle of the natural sciences, but more particularly the atmosphere and the phenomena produced by heat, light, electricity, and magnetism. Although the general laws in relation to thunder and lightning, clouds, rain, hail, snow, frost, land and water-spouts, wind, etc., have, in a measure, been established; yet the laboratory of nature is so immense and complicated in its processes, as to defy the finite powers of the human intellect. Bewildered in the inextricable mazes of causes and effects, the genius of man has never been able to grasp the vast mass of facts presented, and to generalize them in systematic harmony. But fortunately, as in other departments of knowledge, so in that of meteorology, nature has found faithful interpreters content to observe facts and to trace their relations and sequences, thus bestowing upon it the characters of a true science. It is now being daily improved by the results of researches the most varied and extensive. The averages of heat under every variety of general and local causes; its distribution by isothermal, isotheral, and isocheimal lines; its mean at different depths and altitudes, and under the various influences of reflection and radiation; and the temperature of waters;—the phenomena of clouds, dew, and evaporation; of rain, hail, and snow; and the relative quantity of rain in different localities and elevations;—the electrical or magnetic states of the air; the barometrical conditions of the atmosphere; and their periodical or irregular oscillations, as influenced by heat, electricity, the ocean-tides, or lunar attractions;—and the phenomena of winds and hurricanes, as regards their direction, velocity, and physical causes;—all these operations of nature both in regard to the explanation of the phenomena themselves, and their mutual relations and sequences, are at this time the subjects of active and fruitful investigation.

These investigations and those of a kindred nature, tend to show that between the corporeal powers and intellectual faculties of man, and the properties of the various forms of matter which surround him, there exists a mutual harmony. The atmosphere supplies him with the aliment, which alone can support the breath of life. From the same source are derived water, heat, and light,—those universal agents which are equally, but not so immediately, necessary to the wants of man. The mineral kingdom, though not a direct supporter of life, yet sustains, in the form of natural soils, the growth of all vegetation, upon which animal life essentially depends for nutrition; and from this source are also obtained those various metallic and earthy bodies, which are of indispensable importance in the promotion of many of the arts of civilized society. Were the earth a universal plain, it would be void of the life and beauty bestowed upon it by the terrible convulsions by which its mountains have been upheaved; for, as there could be no springs of water, no rivers, no metals for the purpose of tools, or no stone or lime to serve for architecture, and as the atmosphere itself would necessarily be baneful, all animal and vegetable life would languish in its lowest existence. It is thus demonstrated that the external world is admirably adapted to the physical condition of man; and equally obvious is the harmony which exists between that world and his moral condition.

Thus do we behold on every side the evidence of design—the agency of a Supreme Intelligence not only adapting mechanism to an end, but adjusting, as the physical history of our globe proves, the mechanism to the altered conditions under which it was to exist. With every change in the physical state of the earth, for instance, we discover a corresponding change o f organized creation.

point, the temperature of the water being the same as that of the ice, notwithstanding so much sensible heat has been communicated to it by the mercury. Hence, it is obvious that the heat received by the ice has entered among its constituent particles, acquiring a latent existence. On the other hand, when water assumes the solid state, as before remarked, as much heat must be given out as it receives during the process of liquefaction. Before a mass of ice can be liquefied, it must absorb 140° of caloric, that is, 140° inappreciable by the thermometer, or the sensation of touch.

But to return to the meterology of heat. Since the commencement of the present century, this subject has received a proper direction through the laborious researches of the most experienced observers, and the united assistance of the most learned mathematical deductions. Not only have correct stationary observations been made in every region of the globe, but numerous scientific voyages have been performed over every ocean, visiting every point of land, and ascending the summits of the highest mountains. Thus have the most interesting results been obtained, calculated to throw much light upon meteorological phenomena, and upon many points of physical geography. To enable the writer to exhibit, in the following chapters, a connected view of the general phenomena of climate and its influence upon the animal and vegetable kingdoms, it will be necessary to present here a summary of the principal facts known, and laws determined in reference to the superficial temperature of the earth, and its temperature at such depths beneath its surface, and at such elevations above its level as are within our reach, as well as in relation to the temperature of waters.

SUBSECTION 2.—*The Superficial Temperature of the Earth.*

By this is meant the temperature of the atmosphere immediately above the surface of the ground. It is this temperature, when not otherwise expressed, that is always understood by the meteorologist, as indicated by a thermometer protected from the direct or reflected rays of the sun and from the radiation of heat from surrounding bodies. Very different is the temperature indicated by a thermometer fully exposed to solar radiation; but if the thermometer, in the sun's absence, is, in its turn, allowed to radiate freely, the mean of these results, it is quite probable, coincides very nearly with the actual temperature of the earth's surface similarly exposed: and equally probable is it that the average of the whole of such observations, notwithstanding the fluctuations of temperature are much greater than those of the air above noticed, would differ but little from the mean of those made under the latter circumstances. But it is necessary to define what is understood by *mean temperature*. Rigorously, the mean temperature of a day is equal to the sum of the thermometrical temperatures observed every hour or every minute, divided by the number of hours or minutes in the day; but three observations, noted at proper periods, give an expression that scarcely differs from the exact mean of the twenty-four hours.

To determine the laws of diurnal variations of temperature, hourly observations during a whole year were made at Frankford Arsenal, five miles from Philadelphia, in 1835–6, by Captain Alfred Mordecai, of the United States Ordnance Department.* For the present purpose, it is necessary to bring under notice merely the hours of daily mean temperature before and after meridian, by which we will be enabled to ascertain the mean temperature at any place, by two observations, or even by one, during the day. As similar observations have been made by Professor Snell, at Amherst College, Massachusetts,* by Sir David Brewster, at Leith, in Scotland, and by Mr. Snow Harris, at Plymouth, England, it may be well to present the whole in a tabular form. Thus:

	Frankford.	Amherst.	Leith.	Plymouth.
Morning Mean	8h. 36m.	9h. 5m.	9h. 13m.	8h. 9m.
Evening Mean	7h. 35m	7h. 49m.	8h 27m.	7h.

The rule of taking observations adopted by the Regents of the University of New York, and followed in the United States Army, (the data of which last will be extensively brought under notice in the sequel,) Prof. Snell says that he finds to agree very nearly with his own results. These are taken every morning when the mercury shows the lowest degree, every afternoon when it shows the highest, and every evening an hour after sunset. The mean of these observations for the day is found, by adding together the first, twice the second and third, and the first of the next day, and dividing the sum by six. At this time, four observations a day, as already stated are taken at the military posts of the United States.

According to Captain Mordecai, the mean time of minimum temperature is at 4½ A. M., and according to Prof. Snell at 5 A. M. This point varies of course with the seasons, but it will nearly always be attained during the hour preceding the rising of the sun. The maximum point may be assumed at 2½ P. M for all seasons. Were not the maximum and minimum points important data in themselves, it would be well to record the thermometer at the following hours, as recommended by Prof. Snell:—

1st. qr., (Dec., Jan., Feb.,) at 9 A. M. and 6 P. M.
2nd. qr., (Mar., April., May.) at 8 " and 6 "
3rd. qr., (June., July., Aug.) at 7 " and 6 "
4th, qr., (Sep., Oct., Nov.) at 8 " and 6 "

"As these hours of observation have a symmetrical arrangement with regard to the sun's declination, it is believed," says Prof. S., "the rule will be nearly accurate every year at this place, and at other places whose latitude does not differ widely from this."

In regard to the position of the thermometer, it may be here remarked that it should be kept in a situation, unaffected, as much as possible, either by the direct or reflected rays of the sun, or by radiation of heat from surrounding bodies. It should be *fixed*, not merely *hung*, upon a bracket projecting six inches from its support, and it must be *completely* sheltered from rain by a screen, so that the bulb shall never be wetted. The observer, in reading it, should avoid breathing on, touching, or in any way warming, it, by a near approach of his person; and in night observations, additional caution is necessary not to heat it by approximation of the light.

The mean temperature of the year, may be approximately determined also by ascertaining the mean temperature of the month which expresses the nearest equivalent. This is either April or October, the law varying in different climates, as will be more fully explained hereafter. But as the mode of taking a single observation per day is objectionable, on the ground that the maximum and minimum points, are in themselves important data; so, by taking merely one month, we exclude the data for ascertaining the mean temperature of the months and seasons, which are of equal importance, with the annual temperature, as regards the influence of climates on organized creation.

Whatever mode of observation may be adopted, in order to ascertain the mean, it is necessary to add all the results together, and divide the sum by the number of observations. Having determined the mean of the day as above stated, the mean of the month is equal to the sum of the mean temperature of all the days in the month, divided by the number of those days; and the mean of the year is the quotient of the sum of all the monthly temperatures, divided by twelve.

The greater the number of observations, the more accurate will be the mean result. To determine the *absolute* mean temperature of a place, many years of observations are required; and this result is a mere approximation, unless we admit that the changes to which a locality is subject are the result of some regular oscillations of its temperature. And as all observations yet made, independent of any change in the physical circumstances of a locality, tend to prove the stability of climates, there is ground for the belief that the differences in the annual means are real oscillations, the periods of which are to us yet unknown. If we have once determined a certain number of mean annual temperatures, it will be found that they oscillate irregularly; but these variations never exceed several degrees above or below the absolute mean temperature of the locality. The conclusion that these means undergo changes in any ratio of progression, is not warranted by any series of accurate observations made in any country. In tropical climates, these annual results are so similar that a single year of observations generally suffices to determine the exact mean temperature. The case, however, is widely different in the excessive climates of the temperate zones. Even in the comparatively mild climate of Paris, among the means of 21 years there is a difference as great as 4°.8 Fahr. Hence, by adopting any one of these means as an expression of the absolute mean temperature of Paris, an error of this magnitude might occur; but by taking the average of these means, the probable error is reduced to 0°.4. In the most rigorous climate of the United States, at Fort Snelling, Iowa, this dissimilarity among ten annual means, however, is not more than 5°.4. The more dissimilar the results, the greater is of course the necessity to multiply observations, to the end of reducing the deviations from the absolute mean to the lowest possible point.

It is not intended here to treat of the causes which modify climate on the same parallels. But let us take a view of the immense importance of meteorological researches in a country like ours, whose varied and extensive surface has scarcely yet been changed by the hand of man. A mass of facts thus accumulated will prove of immediate practical use to the agriculturist, the philosopher, and the physician; and to future generations, it will serve to determine what changes, if any, time may effect upon the climate of a particular region. A comparative view of the climatic features of both continents promises to confer benefits of the most interesting and valuable nature. The general law of decrease of heat for each parallel, from the equator to the pole, subject as it is to modification from local causes, may be ascertained, as well as that for each vertical height in proportion to its elevation above the level of the sea. We may determine the bounds of each species of vegetation, and draw around the globe series of curves, that is, lines of equal annual temperature, *isothermal* lines—lines of equal summer, *isotheral* curves, and lines of equal winter temperature, *isocheimal* curves. It is pleasing to contemplate such a division of the earth, each isothermal belt, as well as those of winter and summer temperatures, representing zones in which we may trace the causes of the similarity or diversity in animal and vegetable productions. To determine the influence of these zones respectively upon the animal economy in health and the agency exercised in the causation of disease, have proved investigations still more useful and interesting. As climate not only affects the health, but modifies the whole physical organization of man, and consequently influences the progress of civilization, a comparison of these systems of climate, as distinguished into constant and variable climes, or mild and extreme ones, in connection with terrestrial emanations, will reveal to the medical philosopher much that is now unknown, and to the political economist many of the circumstances that control the destinies of a people.

In agriculture, England has been, and to a certain extent still is, our principal school of instruction; but her lessons must be corrected by observing the difference of climate and collateral circumstances. To effect this purpose, a comparative view of the meteorology of both countries would avail much. But the science of meteorology concerns more particularly the horticulturist: for agriculture has for its object the fertilization of the soil and the growth and nourishment of indigenous plants, and such as have by a long course of treatment, become inured to the climate; while horticulture aims not only at a knowledge of the constitution of soils, but aspires to the preserving and propagation of exotic vegetation.

It may be here remarked, that, in regard to certain meteorological phenomena, considerable obscurity still obtains. As in other fields of investigation, genius has often gone forth upon the pinions of speculation, without bringing back any substantial trophies. Among the many questions propounded in relation to the meteorology of heat, one of the most contested is—whether climates have undergone any material change of a permanent character—a theme that will be fully discussed in the sequel. One maintains that density of population, and the cultivation of the soil, render a climate warmer; another asserts his conviction that these causes exert a tendency diametrically opposite; while a third peremptorily denies that any change of climate has occurred. It is not unusual, for example, to institute a comparison between the climate of Europe at the present day, and its supposed constitution 2,000 years ago. Now this is a question which may find a solution in the circumstances presented in the regions of the western hemispheres; for here, even within the memory of living witnesses, the physical aspect of vast districts become wholly transformed. Lo! the mountain and the valley that were yesterday untrodden save by the foot of the red man, are to-day crowded with the life and opulence of civilization. The majestic channels that a few years ago were the scenes of border warfare, are now studded with cities and villages,

* Journal of the Franklin Institute, Vol. 19, New Series.
† Silliman's Journal, Vol. 39.

and their every tributary stream applied to the useful arts. With us two centuries have effected as much as 2,000 years in many parts of Europe. The "Landing of the Pilgrims," in 1620, stands in the same historical relation as the invasion of Gaul or Britain by Julius Cæsar.

SUBSECTION 3.—*Temperature of the Interior of the Earth.*

Although this subject pertains but partially to "The Atmosphere and its Phenomena," yet its general consideration here is deemed necessary to a full elucidation of the meteorology of heat.

Although all nature is now in a comparative state of repose, man being permitted to enjoy the patrimony of this terrestrial globe bestowed by an all-wise Creator; yet the existence of more than two hundred active volcanoes, affords evidence that these ancient causes of disturbance have not entirely died away. That the interior of the earth has a much higher temperature than its surface, is an opinion sustained by many facts. It is strongly supported by the appearances presented by rocks in almost all countries; and the lavas ejected by volcanic action are so analogous in appearance and composition to some of the trap-rocks, that an identity of origin seems fairly warranted. Observations made upon the temperature of mines, also afford the most undeniable affirmative evidence, notwithstanding some geologists have attributed the increased temperature to local causes. This result is based upon upward of 300 observations, at depths varying from 150 to 1700 feet, made in various countries. The observations made on Artesian wells, likewise, all tend to confirm the same deduction. At Paris, water has been recently obtained by this process at the depth of 1837 English feet, after seven years of assiduous toil. The torrent of water, three cubic yards per minute, rises in a copious fountain and very pure. Its source is about one-third of a mile below the surface, and spouts thirty feet above the ground. The temperature at the bottom is 83° Fahr. M. Arago has been enabled from a great number of observations of this kind, to deduce some general laws, such as, judging of the depth of the well by the temperature of the water, and, conversely, predicting the temperature of the water from a knowledge of the depth from which it was drawn.

The opinion, that the temperature of the earth increases with the depth beneath the invariable stratum, is also corroborated by the phenomena of thermal springs, if we exclude from the class the Geysers of Iceland, and other analogous phenomena evidently dependent on active volcanoes. In many of these thermal springs, it has been observed that the temperature remains unchanged during a long series of years. It is shown by M. Legrand, from observations extending from 1754 to 1819, made in many of the thermal springs of the eastern Pyrenees, that the difference in temperature exceeds at no time 1 2-10 degrees of Reaumur, and generally there is no variability.

As early as 1671, it was discovered that the temperature of the cellars beneath the Royal Observatory of Paris, at the depth of 27 metres or 85 French feet, experienced no variation during the course of the year. In 1771, this fact was shown by more precise data, which were the result of a series of experiments instituted by the Count Cassini; and in 1783, the same philosopher, in conjunction with the celebrated Lavoisier, finally completely established its truth. It has now been demonstrated that the temperature of these cellars, during a period of fifty years, is constantly at 11.° 82 centigrade, being about 53¼° of Fahr. This constitutes the invariable stratum of temperature, which is uninfluenced by the alternations of days and nights, and the succession of the seasons. From this point to the surface of the earth, the temperature is influenced by the causes just mentioned; but beneath the invariable stratum, it is a rule that it increases with the depth. It is also found that the depth of this stratum of invariable temperature varies much in different countries. While in our excessive climate, it lies 80 feet beneath the surface, it is within one or two feet of it in the equinoctial regions; and as the temperature of the invariable stratum never deviates much from the mean annual superficial atmospheric temperature of the corresponding place, the traveller within the tropics can, at any time, determine two important data, by merely burying a thermometer for an hour in the ground. The ratio in which temperature increases with depth is very dissimilar in different localities. To obtain an augmentation of 1° centigrade, according to M. Cordier, it is necessary to penetrate in some places 13 metres and in others 57.† The experiments of MM. Arago and Dulong, and those of M. Walferdin, give for each degree the following results:—Estimating from the surface at Paris 30 41-100 metres, and estimating from the invariable stratum in the cellars of the Royal Observatory, 30 11-100 metres. Assuming that the law warranted by these data holds good, the heat at the depth of about a mile and a half is not below that of boiling water; and at a very small depth, (say 60 miles,) in comparison with the radius of the earth, the most of matter must be in a state of incandescence.

Although the doctrine that the centre of the earth is in a state of igneous liquidity, is not new, yet it is only of late years that it has been proved by experiment. Based upon this opinion, we have had hypothesis upon hypothesis, ever since the days of the ancient philosophers,—the wildest vagaries, serving but as monuments to perpetuate the folly of great minds. One fancies that the earth must be a fragment of the sun, ejected from that body in a liquid and ignited state; while another supposes it to be a part of a comet, which, by some adventitious circumstance, fell within the attractive influence of the sun, which has exacted from it, ever since, an undeviating attendance. Thus has system arisen beside system like the moving pillars of the desert; but like them, they have proved fabrics of sand. Various attempts, which it is deemed unnecessary to notice here, have also been made to explain upon philosophical principles the law of an increasing interior temperature, without adopting the supposition that the entire globe was originally in a state of fusion, or at the present time in a state of igneous fluidity.

To determine the movements of temperature, in accordance with the seasons, from the surface of the ground to the invariable stratum, presents an ample field for observation. The results already revealed give the promise of many other important and useful facts. The following is a summary of the results obtained:—During December, January, and February, the temperature, as it is then at its minimum at the surface of the earth, increases in a nearly uniform manner down to the invariable stratum. During March, April, and May, the temperature decreases rapidly to the depth of one or two feet; below this depth, the decrease is less rapid; and still lower, the temperature increases a little. During May, June, and July, the temperature, which is then at its maximum at the surface, slowly decreases downward to a considerable depth; it then begins to increase moderately till it attains the temperature of the invariable stratum. In August, the temperature, from a little below the surface to the stratum of invariable temperature, continues to decrease in a nearly uniform manner. In September, the temperature, to the depth of fifteen or twenty feet, is nearly uniform, when it decreases a little and slowly to the stratum of invariable temperature. In October and November, the temperature increases to the depth of 15 or 20 feet; from which point to the invariable stratum, it remains nearly uniform. These changes, however, seem to fluctuate considerably, not only in different places on the same isothermal line, but in the different seasons of the same locality.

In descending into the earth, the mean annual temperature augments gradually, with the exception of a stratum lying about half a foot beneath the surface. The temperature of the surface of the earth participates very much in the fluctuations of the incumbent atmosphere, being generally, however, a little above it by day, and below it by night; but these results will depend much upon the nature of soil, as for example its radiating and conducting power. The extent of these fluctuations at the depth of thirty inches, as determined by a series of observations conducted by the author, for the period of one year, on Bedlow's Island, in the harbor of New York, will be presented hereafter. In fine, wherever observations with the thermometer have been made beneath the invariable stratum, the rule that the temperature increases with the depth has yet found no exception. Observations in deep caverns and mines, on Artesian wells, and in the cellars of the Royal Observatory at Paris, all coincide, as has been already shown, in this result. As the ratio in which temperature increases with depth is very dissimilar in different localities, many of the apparent anomalies of temperature, observed in different places, rendering the latitude of a country no index of its climate, have been ascribed by some of the French *savans*, with very little show of reason however, to the comparative thickness, or powers of conduction, of the geological strata which envelope the liquid interior in a state of incandescence.

SUBSECTION 4.—*Temperature at different elevations above the surface of the Earth.*

In regard to the law of the distribution of sensible heat through the atmosphere, our knowledge is not precise. It is known that the temperature decreases as we ascend, but we know not whether there exist strata of invariable temperature. We are equally ignorant whether the decrease takes place uniformly, or whether it changes with latitude and the different seasons. The mean furnished by a table of thirty-eight observations by M. Garnier, shows a decrease of 1 deg. centigrade for every 164 7-10 metres of elevation. According to M. Laplace, the same diminution of temperature is caused by 176 metres; and according to Guy-Lussac, as determined by a balloon ascension, it is 171 metres. Prout says that every hundred yards of altitude, as a general average, causes Fahrenheit's thermometer to sink one degree. According to Humboldt, the thermometer at the equator, falls 10 deg. in the first 1000 yards of ascent, or about 1 deg. for 300 feet. In the next 1000 yards, it is only 1 deg. for 524 feet; but in the third and fourth stages, a remarkable acceleration occurs, which is again diminished in the fifth stage to 1 deg. in 320 feet. A fall of 1 deg. for every 341 feet, is the mean rate in the variation of temperature, throughout the whole elevation of 15965 feet, at the limit of perpetual snow. Humboldt ascribes the smaller rate of decrease in the second and third stages, to the large dense clouds which are suspended in the region, which have, in his opinion, the triple effect of forming rain, absorbing the sun's rays, and intercepting the radiation of heat from the earth. In the temperate zone, a difference of 1000 yards in height will produce a difference of 12 deg. of temperature. An ascent of 100 yards in the temperate zone, it is calculated by Humboldt, diminishes the temperature as much as an additional degree of latitude. But in this respect there is a wide difference between extensive table lands and insulated peaks, as will be fully illustrated in the sequel.

The causes upon which this diminished temperature in the higher regions chiefly depends, are—first, the perfect permeablity of the atmosphere to the solar rays, and, secondly, its increased capacity for caloric in proportion as it becomes rare. As the solar rays radiate through the atmosphere almost without affecting its temperature, it follows that the temperature of its lower regions is derived more immediately from the earth. Although the atmospheric stratum immediately incumbent on the surface of the earth, owing to the rarefaction, naturally ascends, yet as its capacity for caloric at the same time increases, it loses rapidly its sensible heat. Hence, as we ascend into the atmosphere, its temperature diminishes precisely in the ratio that its latent heat, that is, its capacity for caloric as produced by rarefaction, increases.

SUBSECTION 5.—*Limits of Perpetual Snow.*

Closely connected with this subject are, the *limits of perpetual snow* in different latitudes. The perpetual snows which cover high mountains, are, on the one hand, the effect of decrease of atmospheric temperature, and, on the other, a cause of this decrease, at least in the surrounding atmosphere. The inferior limit of this congelation, which may be naturally supposed to follow the degree of melting ice, is subject to many modifications. Reaching in different seasons and in the same season of different years, a higher or lower point, these limits, the annual oscillations of which are dependent chiefly upon those causes which influence the temperature of the hotter months of the year, vary greatly in different latitudes. These influences have reference to the nature and inclination of the ground, the prevalence of certain winds, and the general condition of the atmosphere, as respects its serenity, humidity, &c.: and independent of these physical conditions of the locality, the inferior limit of perpetual snow will also be more or less elevated in proportion to the quantity of snow already accumulated. Under the equator, perpetual snow exists generally at an altitude of between 15,000 and 16,000 feet, while in the 70th deg of N. lat., it is found at the height of 3,300 feet. Receding from the equator, these phenomena assume a more irregular character. The difference between the limits of perpetual snow on the northern and southern sides of the Himmaleh mountains, is not less than 4000 feet; and while these limits are at the

† A metre contains 39 371-1000 English inches.

equator nearly 3° above, they are in the frigid zone more than 10° below the freezing point.

To explain the diminution of temperature on the summits of high mountains, no longer, therefore, presents any difficulties to natural philosophers. As the atmosphere is rare and diaphanous, but a small portion of the heat of the solar rays which traverse it, is retained; and as the more dense inferior strata, heated by the surface of the earth, expand, rise up, and grow cold from the circumstance alone of their rarefaction, they encounter these summits, and rob them of their caloric, which passes into a latent state.

This subject not only presents one of the most interesting problems in meteorology, but it is intimately connected with the laws of the geographical distribution of plants and animals. Hence no opportunity of studying all the circumstances connected with this phenomenon, should ever be lost by the intelligent observer. The principal facts demanding attention are—to fix its precise geographical position, and to describe the locality in relation to its general configuration and the nature of the soil, to determine the elevation of the inferior limit of perpetual snow above the level of the sea, to ascertain the extent of the annual oscillations of this line, and also the mean annual temperature of the atmosphere at that elevation.

In the whole economy of nature, there is not presented a more important provision than the perpetual snow resting on the summits of high mountains. In the warmer climates, this accumulated snow becomes the source of innumerable rivers, without which those regions would be unfit as a residence for man.

Subsection 6.—*The Temperature of Waters.*

Without reference to *thermal* springs, it may be remarked that the temperature of those, not very remote from the surface, which flow abundantly, varies in accordance with the different seasons. In the northern hemisphere, they generally reach the highest degree of heat in September, and the lowest in March, the difference between these two periods not exceeding more than 2° or 3° Fah. In the torrid zone, the mean temperature of the air is generally a little higher than that of the springs; while in the temperate zone, the springs are little warmer than the air. The excess of temperature of springs, as compared with the mean annual temperature, increases with the latitude; for, while from the 30th to the 50th deg. of latitude, it is only 2° it rises, between the 60th and 70th parallels, to 5°–7° Fah.—Small springs that rise slowly take, to some extent, the temperature of the beds which they traverse; but the waters of those that flow abundantly maintain, in reaching the surface, the temperature of the strata in which they are formed.

In respect to those springs which undergo slight changes with the seasons, it is reasonable to suppose that they have their origin and subterranean flow between the surface of the earth and the invariable stratum. Hence their sources, even in our climate, cannot be lower than 60 or 80 feet. Springs of a constantly uniform temperature, on the other hand, have their origin below the invariable stratum. In regard to this class of springs, it has been shown by M. Arago, as already remarked, that the depth of the well may be calculated from the temperature of its waters, and conversely the temperature of the water may be predicted from a knowledge of the depth to which the well is bored. These remarks, which apply only to natural springs, have no reference either to thermal springs, or those sudden eruptions of water, gas, or mud observed in various countries, and especially in the vicinity of active volcanoes.

The temperature of lakes and rivers offers a fruitful field of inquiry. The temperature of the surface of lakes has a close relation with the climate and season; but at the bottom, or at a certain depth, of deep lakes, little or no change of temperature is experienced throughout the year. As the heated portions of a fluid float on the surface, while the colder will sink by their superior gravity, it follows that the bed of a deep pool is always excessively cold; and at these depths, it approaches the temperature which corresponds to the maximum density of water, which is variously estimated from 39° F. to 42.°5. Few or no experiments have yet been made on the lakes of the United States. According to Saussure, the bottoms of the majestic basins of the Alps, whether in the lower plains or elevated regions, are nearly all equally cold, being only a few degrees above the point of congelation. In Lake Geneva, at the depth of 1000 feet, this accurate observer found the temperature to be 42°; and beyond 160 feet beneath the surface, he could discover no monthly variation. In the lakes of Scotland, the variable impression of the seasons would appear not to penetrate more than fifteen to twenty fathoms; and consequently, below this point, a uniform coldness prevails. In Loch Catrine and Loch Lomond, the temperature, at all depths below 40 fathoms, has been stated at 41°, while the mean for the climate is 47°. The temperature of Lago Sabatino at Rome, at a depth of 80 fathoms, is 44°.5, which may be accounted for by the circumstance that thermal springs, when they occur at the bottom of a lake, may keep up the temperature. It is seldom that deep lakes freeze, except in a very cold climate, because the whole body of water must sink below 40° before congelation can commence.

It is thus seen that the law of the distribution of heat operates, in a liquid mass, very differently from what it does in a solid. Although capable, like solids, of conducting heat slowly through their mass, yet it is transferred principally in a copious flow by their internal mobility. All experiments yet made lead to the conclusion that the temperature of the water of deep lakes beyond a certain depth, is nearly constantly, or perhaps always, the same, and much lower than the mean temperature of the country. In respect to rivers, in consequence of the constant intermixture of the upper and inferior strata by the motion imparted to the watery molecules, the distribution of heat is not the same as that of lakes. There is a difference, however, in the motion of the water at the surface and at the bottom of the river, as well as on the sides compared with the middle. Hence arise a multitude of interesting phenomena, open to further investigation; for of all these, the subject of congelation is the only one that has been prosecuted with much success. The numerous lakes and rivers of the United States afford the most ample opportunities, to those interested in these questions, of instituting experiments. As regards theremometrical observations, it is necessary that these be made at the surface and at the bottom of lakes and rivers, once a month, and continued for several years. In summer, it should be determined to what depth the heat will reach; and in winter, the temperature of the surface water at the moment of freezing should be ascertained. Other points of inquiry will present themselves; as, for instance, whether in stagnant waters the process of congelation always commences at the surface, without ever extending to any considerable depth; and in regard to running waters, in which the process, as a general rule, commences at the bottom, whether the surface waters, are not, under certain circumstances, the first to freeze.

Temperature of the Ocean.—Within the tropics, little or no difference is presented between the temperature of the surface of the ocean in the northern and southern hemispheres; but as the poles are approached, it decreases more rapidly in the northern than in the southern. Even in the northern hemisphere, however, there must be a difference in the temperature of the ocean in the same latitude on comparing the vicinity of the eastern and western coasts of our continents, as will be hereafter satisfactorily demonstrated. The mean temperature of the ocean at the surface, at a distance from land, is higher than that of the superincumbent atmosphere; but it is generally higher than the atmosphere at midnight, and lower than the air at mid-day. Between the tropics, the surface of the sea has a mean temperature of about 80°, the range being from 77° to 84°; and beyond them, notwithstanding a steady decrease, there is much fluctuation, as cold icy currents, on passing into lower latitudes, depress the temperature, while the reverse holds in regard to currents from the torrid zone. The temperature of the ocean is much more constant than that of the superincumbent atmosphere; and it has scarcely any diurnal range, unless the water is shallow, as over a bank. This fact, by the way is important as serving to enable a seaman, when the atmosphere is obscure and his reckoning doubtful, to determine his approach to land. A considerable number of experiments have been made on the temperature of the sea below the surface by Piron, Ellis, Flinders, Ross, Parry, and others; but, though it generally decreases on descending, the results are not according to any known or uniform law. For instance, at a depth of five fathoms, there is sometimes a reduction of 1°, while in other instances the same reduction requires 100 fathoms. Sometimes the minimum temperature is found at the depth of 100 fathoms, and again it requires 400 or 500 fathoms. According to an experiment by Capt. Sabine, the temperature of the Carribbean Sea, at a depth of 1000 fathoms, was 45°.5, while its surface was 83°; but as the pressure at this depth is enormously great, the ball of the thermometer may have been so compressed as to have kept the temperature of 45°.5 above the truth. Although in the tropical seas, the Mediterranean, and Baffin's Bay, the temperature diminishes with the depth, yet in the Greenland seas and the Arctic ocean it increases. It has been determined that the rate of increase of temperature in the Arctic Sea has as inconstant a connection with the depth as the decrease in the temperate and torrid zones. Thus Mr. Scoresby, who first ascertained the fact that the temperature augments with the depth, found an increase of 6°.6 and 8° at the respective depths of 120 and 730 fathoms; Capt. Sabine, 7°.5 at 680 fathoms; Capt. Parry, 6° at 240 fathoms; Mr. Fisher, 9°.5 at 188 fathoms; and Lieut. Beechy, 10° at the depth of 700 fathoms. Sea-water, in its natural state, freezes at about 28°; but when it has been concentrated by previous congelation, the freezing point is reduced to 15° or 16.° When saturated with salt, water, it is said, does not congeal at a temperature above 5°. The waters of the ocean from this cause, and from the additional influence of its immense depth and extent, become very rarely frozen, except in latitudes in which the most intense cold prevails. After congelation, the temperature has been observed to sink as low as—55°; but even a lower temperature than this, doubtless, occurs in the polar regions.

As connected with a general theory of the distribution of heat over the globe, the observations which have been made, in all parts of the ocean, both at its surface and at various depths by the most skilful navigators of different nations, have been of much importance to meteorology.

SECTION IV.—Accidental Atmospheric Phenomena.

The remaining phenomena that pertain to meteorology may be termed *accidental.* A large class are occasioned by foreign substances suspended in the atmosphere, in which, according to circumstances, they accumulate more or less rapidly, and from which they disappear either quickly or slowly. Among these may be enumerated, dew, frost, fogs, clouds, rain, snow, hail, etc., as well as the fall from the atmosphere of different meteoric substances. Into the origin, the properties, and the various appearances of these substances, it is now proposed to inquire.

Subsection 1.—*Water in the Atmosphere.*

That which exerts the greatest influence in the production of the majority of atmospheric phenomena, is watery vapor suspended in the atmosphere. That water does not exist in the air in a state of solution, but as elastic vapor, is evident from the fact that it will evaporate more rapidly under an exhausted receiver than in the open air. This is also proved by comparing a series of experiments made by Saussure at Geneva with a similar series on the Col-du-Géant, about 1000 feet higher. On the supposition that the temperature and dryness of the air were the same at both places, the evaporation at the upper to that at the lower, would be nearly as 7 to 3; and hence the rate of evaporation was more than doubled, while the diminution in the density of the air did not exceed one-third. Water assumes the form of vapor at the lowest point of the thermometer, but the rate of its evaporation, as a general law, increases with the temperature. The only limit to this process is the saturation of the air with moisture, when the pressure exerted is sufficient to prevent any further evaporation. But in this process, it is absolutely necessary to consider the temperature of the liquid from which the vapor is rising; for when the temperature is high, the force exerted against the evaporation by atmospheric vapor is wholly inappreciable. These remarks, however, have reference to the formation of vapor at common atmospheric temperatures only; and hence it has been correctly termed *spontaneous evaporation.* This process is constantly going on from every moist surface, and even from ice and snow. Thus it has been ascertained that, in the month of January, a circular area of snow five inches in diameter has yielded 150 grains of vapor, between sunset and sunrise; and before the next evening, fifty grains more were formed, the gauge being exposed to a smart breeze on the house-top. Hence, under like circumstances, the enormous quantity of 64,000,000 grains of moisture, would be evaporated in the course of twenty-four hours, from a single acre of snow. Even during the night only, a thousand gallons of water would be evaporated from the same area of

now. It is, therefore, no ways surprising that a moderate fall of snow will sometimes entirely vanish during a succeeding northerly gale, without the slightest perceptible liquefaction on its surface. It has been already stated, as a general law, that the rate of evaporation, as well as the actual quantity of water in the state of vapor in the atmosphere, increases with the augmentation of temperature. The law of this increase, however, is not regular; but it will suffice the object now in view, to state that, at all atmospheric temperatures below the boiling point of water, while the increase of temperature advances in *arithmetical progression*, being *slow* and uniform, the corresponding rate of the elastic force of vapor, by which the quantity of water as vapor is determined, increases so *rapidly* as to be nearly in *geometrical* progression. Above 212°, the law of the elastic force of vapor is very different from what it is below the boiling point. As water at 212° exists in the gaseous form, it obeys precisely the same laws and exerts the same elastic force, under similar circumstances, as atmospheric air does. But compared with atmospheric air at the temperature of 32°, how wide is the difference! While at this temperature water is a solid, and the force of the elasticity of its vapor is equivalent only to about 1-5th of an inch of mercury; the atmospheric air, on the other hand, may exert an elastic force equal to the weight of a column of mercury thirty inches high.

If water is evaporated in closed vessels, it may be again obtained by the action of certain substances that have a great affinity for water; such as quicklime, chloride of lime, carbonate of potassa, and sulphuric acid. As they absorb the moisture of the air, the weight thus acquired has been taken as the measure of the quantity of its water. From some very careful experiments thus conducted by Saussure, he concluded that a cubic foot of air completely saturated with moisture, at the temperature of 65° Fahr., holds eleven grains of water dissolved. But the method of Dr. Dalton, which consists in observing the temperature at which moisture begins to be separated from the air, is preferable. This, which is termed the *Dew-point*, constitutes a valuable element in several important problems in meteorology.

SUBSECTION 2.—*Condensation.*

¶ Intimately connected with evaporation are the phenomena of *condensation* of vapor from the atmosphere. As a reduction of its temperature causes a diminution of the capacity of the air for moisture, it follows that when vapor, at any given temperature, is cooled below the point of saturation, a portion is separated in the form of fluid water, while the elastic condition proper to the newly acquired and diminished temperature, is assumed by the remainder. Thus the temperature may be diminished by mingling with colder currents in the atmosphere, when a quantity of water is separated, which, according to the suddenness of the change, will be either suspended in the form of visible clouds, or precipitated in fogs, rain, or hail. These two processes of evaporation and condensation, by a beautiful provision of nature, have a constant tendency to control each other's operations; for, while the former is increased by heat and produces cold, the latter is produced by cold and liberates heat. Another arrangement no less wonderful is, the fact that water raised by evaporation is freed entirely from all foreign substances, and is thus condensed in a state of absolute purity.

It is thus seen that the degree and rate of evaporation, notwithstanding they increase with the temperature, are regulated chiefly by the existing degree of saturation of the air. Hence there can be neither evaporation nor condensation in an atmosphere perfectly saturated with moisture, and in a state of thermal and dynamical equilibrium. "The processes of evaporation and condensation," says Prout, in his Bridgewater treatise, "always indicate a disturbance of the thermal equilibrium in some part of the atmosphere: condensation denoting a depression of the temperature below the mean, or point of thermal equilibrium: evaporation, on the contrary, denoting that the temperature in some part of the atmosphere has been raised above the mean: or at least that the temperature having been depressed below the mean, is again undergoing an elevation to the mean point. Evaporation and condensation may be thus considered as mutually dependent; so that one process cannot take place without the other. For this reason, in the great expanse of nature, these two processes oscillate or fluctuate about the point of equilibrium, within certain limits which are never passed; and which limits, though subject to countless anomalies, in general, decrease from the Equator toward the Poles."

It thus appears from the preceding remarks that the only fluctuating ingredient in the composition of the atmosphere as regards its permanent gases, (for its oxygen and nitrogen have been found to be the same on the summits of lofty mountains and in the narrow lanes of cities,) is its aqueous vapor; and to determine this varying quantity is an object of the highest importance. The principal property of this vapor, demanding our attention, is its *elasticity*; and hence it becomes necessary to bring under consideration the means employed to measure the elastic force of atmospheric vapors.

SUBSECTION 3.—*The Hygrometer.*

Hygrometers, or measures of moisture, are the instruments used for this purpose. They are of two classes, the one giving the measure immediately, and the other furnishing the result only indirectly and by means of inductions more or less uncertain. The former are generally constructed on the principle of the condensation of vapor. The latter consist of a variety of animal and vegetable substances, which change in bulk from the absorption of moisture. For example, among vegetables there have been employed for this purpose, a cord of flax or hemp, which twists and untwists by moisture and dryness,—the beard of the wild oat, *avena fatua*, which possesses a natural twist,—the Indian grass, *andropogon contortum, cum multis aliis*. Among animal substances, the most simple hygrometer is Wilson's, which consists of a rat's bladder, fastened to a glass tube, filled with mercury. By Saussure, a fine human hair, freed from unctious matter by boiling it in a weak alkaline solution, was employed; and De Luc made use of a slip of whalebone, scraped extremely thin. Both of these instruments were graduated by placing them in a jar filled with air saturated with moisture, and then in air dried by quicklime, or some other substance having similar properties; after which the space between these extreme points, was divided generally into one hundred degrees. Although indicating minute changes in the air, yet these substances are incapable of forming *comparable* hygrometers; to which must be added an equally fatal objection, that time alters their mobility and delicacy. Even the hair hygrometer of Saussure, notwithstanding both Gay Lussac and Biot gave to this instrument all the exactitude of which its construction is susceptible, is not entitled to confidence. Among the first class—those constructed on a simple and rigorous principle, giving at once the exact value of the element required—the hygrometer of Daniell takes the preference decidedly. As it is quite portable and exact in its indications, it is a valuable meteorological instrument; but all of this class are liable to the objection that it is somewhat difficult, especially at low temperatures, to determine the precise degree at which dew begins to be deposited.* In Daniell's hygrometer, the only results which it is necessary to enter on the register are, the temperature of the dew-point and that of the surrounding air; for the first of these two data enables us, by reference to tables calculated for this object, to determine the elastic force of the vapor and its weight; and the comparison of the two data gives the degree of humidity of the air at the time of observation. As air containing the same quantity of vapor does not necessarily possess the same degree of moisture, inasmuch as this quality depends upon the temperature of air at the time of observation, it becomes necessary to compare the temperature of the dew-point with that of the surrounding air. When the air is nearly saturated, a very slight diminution of temperature is attended with the formation of dew; or, in other words, if these two temperatures are nearly equal, the air is almost saturated with vapor. But if, on the contrary, the air is dry, a body must be considerably colder before moisture is deposited on it; or, in other words, if the temperature of the surrounding air exceeds considerably that of the dew-point, the air is regarded as very dry. In a word, the less humid the atmosphere, the greater will be the difference between its temperature and that of the dew-point. By attending to these two simple results, we may obtain all the elements required in the explanation of the meteorological phenomena dependent on the presence of elastic vapor in the atmosphere.

Another mode of obtaining a measure of the hygrometric state of the air is by comparing the indications of a thermometer with its bulb moist and dry—an idea which is due to Dr. James Hutton, the celebrated geologist. These are so constructed that two thermometers are mounted on the same scale, thus enabling us to see, at the same time, the indications of the wet and dry bulbs. The hygrometer, or double air-thermometer, of Sir John Leslie, is constructed on this principle; but it does not indicate the absolute dryness of the atmosphere, but merely the degree of dryness it has after being reduced to the temperature of the humid ball. We here determine the hygrometric condition of the atmosphere, by ascertaining the degree of refrigeration produced by the evaporation of water. An easy method of finding this, is to cover the bulb of the thermometer with a wet rag, and swing the instrument in the air for a few moments; and then noting the difference between this temperature and that marked by the dry thermometer.

As regards the proper period of making hygrometrical observations, the author cannot recollect having ever met with very precise directions, except in those cases in which they are required to be made every one or two hours. But as few persons could be found disposed to engage in so tedious an undertaking, it is fortunate that by making two observations daily, the three most important results may be obtained, viz., the maximum, the minimum, and the mean. Now as it is very probable that the maximum and minimum temperatures of the air in the 24 hours, correspond with the maximum and minimum temperatures of the dew-point, the proper times of observation are at three o'clock P. M., when the maximum temperature occurs, and in the morning between dawn and sunrise, when the lowest degree generally is found.

The "directions" for observations on the wet bulb in the army of the United States, read thus: "The hygrometric condition of the atmosphere may be determined by ascertaining the degree of refrigeration produced by the evaporation of water. The most easy method of finding this, is to wet the bulb of a thermometer, covered round with fine gauze, and swing the instrument in the open air, in the shade, for a few moments, till the mercury sinks as low as it will. * * Water should not be poured upon the bulb of the thermometer, but appled with a bit of sponge, a fine brush, or any similar substance, and when the temperature is near, or below the freezing point, care should be taken simply to *moisten* the gauze. * * The wet bulb is taken at sunrise and at 3 P. M."

Let us now turn our attention to the mode by which the elastic vapor of the atmosphere is reconverted into moisture.

SUBSECTION 4.—*Dew.*

This phenomenon may be thus explained, in a general way: When the direct influence of the sun is removed in the evening, the surface of the earth, in consequence of the ceaseless activity of caloric to maintain a state of equilibrium, radiates a portion of its superfluous temperature into surrounding space; and as the temperature of the air immediately in contact with the surface thus becomes reduced below the point of saturation, a part of its water is condensed in the form of dew.

Ever since the time of Aristotle, the phenomena and cause of this deposition have engaged the attention of philosophers; but until the comparatively recent experimental investigations of Dr. W. C. Wells, all our views on this subject were merely speculative. The fact that the bodies on which dew is deposited have invariably a lower temperature than the ambient air, had been pointed out by Dr. Patrick Wilson of Glasgow; but while this coldness was supposed to be the *effect* of the deposition of dew, it was reserved for Dr. Wells to make the important discovery that it *always precedes the formation of dew*, and is in reality the *cause* of this aqueous vapor.

Prior to the appearance of Dr. Wells' elegant "Essay on Dew," it was a disputed question among philosophers whether the phenomenon is produced by the rising of vapors from the earth, or by its descent from the atmosphere. The circumstance that the glass-bells with which gardeners cover plants during the night, have, in the morning, their in-

*Since writing the above, the author has satisfied himself that Daniell's hygrometer is unadapted to the dry climate of the United States, with the exception perhaps of our southern borders. This conclusion was arrived at by a recent army medical board, after a full and patient investigation of the subject.

terior covered with moisture, gave origin, it is said, to the opinion that this humidity arises from the earth. Dr. Dufay, a French philosopher, maintained this opinion, based on the following experiment. Taking two long ladders, he fixed them so that they met at the top and were wide apart at the bottom, and attached to the several rounds large panes of glass. Observing that the lower surface of the lowest pane was first wetted, then the upper, next the lower surface of the one above it, then its upper, and so on to the top of the ladders, he deduced the conclusion that dew is caused by the exhalation of vapors from the earth during the night. On the other hand, it was urged, in proof of the descent of vapor, that in cloudy weather little or no dew is formed. The fallacy of both these hypotheses has been proved by Dr. Wells, by a most beautiful inductive process, in which he shows that dew is produced by the condensation of the atmospheric vapor surrounding the bodies on which it is deposited. There were other difficulties still more perplexing connected with the first question—Does the vapor producing dew rise or fall? For example, while some substances receive the deposition of dew very readily, there are others on which it cannot be deposited. But every circumstance connected with this phenomenon finds the most satisfactory explanation in the beautiful theory proposed by Dr. Wells, and now universally adopted by philosophers,—a theory which depends upon two principles, viz., the nocturnal radiation of caloric and the condensation of invisible vapor. One important lesson at least is taught by the history of these opinions, which is, the absolute necessity of basing our theories upon authenticated and well investigated experiments, carried out under the guidance of legitimate deductions.

According to the theory of Dr. Wells, there are five essential requisites for the deposition of dew.

1. *An atmosphere replete with moisture.* That the moisture must be in excess before it can be deposited is evidenced by the fact that in Egypt no dew is formed when the winds blow from the south over the extensive tracts of sandy desert; but as soon as the wind changes to the north, laden with moisture from the Mediterranean, the deposition is remarkably great. 2. *The difference between the temperature of the earth in the day and the night must be considerable.* Consequently, the deposition is greatest when a sultry day is followed by a cool evening; and, for the same reason, the dews are most abundant, in our climate, in spring and autumn, as then the difference of temperature is greatest. But hot climates have more copious dews than temperate countries, notwithstanding the difference between diurnal and nocturnal temperature may be less in the former,—a fact that finds an explanation in the circumstance that an increase of temperature is attended with more than a corresponding increase of moisture. This fact, the author can confirm from personal experience in East Florida. 3. *A serene and cloudless sky.* Notwithstanding the atmosphere may be in other respects favorable, little or no deposition, if the sky is veiled in clouds, occurs; for, as the caloric radiated from the earth is reflected back by the clouds, the temperature of objects on its surface is little diminished. Screens of an opaque material interposed between the sky and the surface of the earth, produced the same effect; and accordingly a thermometer laid on a table, compared with one placed on the ground beneath it, indicated a lower temperature. Even fogs which are precipitated from the higher air, acting as screens, are unfavorable to the deposition of *true* dew, which is separated from the inferior atmospheric stratum. 4. *Serene and calm weather.* This follows from the circumstance that if the lower atmosphere is in violent motion, it will maintain the general temperature of bodies on the surface of the earth; and hence, too, every condition which favors radiation, as a dark color or a rough surface, contributes to the deposition of dew. 5. *The temperature of the body upon which the dew is deposited must be considerably lower than that of the ambient air.* This is the most essential requisite. Dr. Wells, in his experiments found the bodies on which dew formed, to be 10° or 15° colder than the atmosphere.

Different bodies, according to their constitution, possess different powers of radiation; as, for instance, metals and vitreous substances are, in this respect, in very opposite extremes. Bad conductors or bad reflectors, are, as a general law, good radiators; but the power of radiation, as just remarked, depends greatly upon the nature of the surface. Hence a piece of wool, or a plate of glass placed in a horizontal position, favors the deposition of dew; but a piece of polished metal will retain its lustre, notwithstanding every blade of grass around it may be drooping with the pressure of condensed vapor. These facts lead at once to the deduction that, during the night, the temperature of different substances varies in accordance with their respective powers of radiation and conduction.

Thus have these deductions been developed by Dr. Wells in a long series of experiments, as conclusive as they are ingenious. His admirable work is well worth being consulted by every one who takes an interest in physical facts as a science, or by the mere practical horticulturist. His extensive observations have enabled him to apply many useful precautions to the cultivation and preservation of fruits, flowers, and plants. Thus the effect produced by the intervention of a substance between the radiating body on the surface of the earth and the upper regions of the air, which are well known to be the abodes of perpetual congelation, has an important bearing on horticulture. Even a thin wire gauze, suspended over a body which readily admits the deposition of dew, will suffice to prevent its occurrence. "I had often," says Dr. W., "in the pride of half-knowledge, smiled at the means frequently employed by gardeners to protect plants from cold, as it appeared to me impossible that a thin mat, or any such flimsy substance could prevent them from attaining the temperature of the atmosphere, by which alone I thought them liable to be injured. But when I had learned that bodies on the surface of the earth become, during a still and serene night, colder than the atmosphere, by radiating their heat to the heavens, I perceived immediately a just reason for the practice which I had before deemed useless. Being desirous, however, of acquiring some precise information on this subject, I fixed, perpendicularly, in the earth of a grass-plot, four small sticks, and over their upper extremities, which were six inches above the grass, and formed the corners of a square, the sides of which were two feet long, drew tightly a very thin cambric handkerchief. The temperature of the grass which was thus shielded from the sky was upon many nights afterwards examined by me, and was always found higher than that of the neighboring grass which was uncovered, if this was colder than the air."

The result of an experiment will be vitiated as much even by the vicinity of a house or a tree, as if a substance were actually interposed between the earth and the sky. It is well known that, in spots shielded by the spreading branches of a tree, dew is much less abundantly deposited. This fact was not unknown to that prince of poets, Milton, who says—

> Full forty days he passed, whether on hill
> Sometimes, anon on shady vale, each night
> Under the covert of some ancient oak,
> Or cedar, to defend him from the dew.

As dew not unfrequently partakes of the sensible qualities of the bodies upon which it is deposited, it has sometimes been erroneously confounded with foreign substances. "What is termed *honey-dew*," says Dr. Traill, "generally owes its qualities to the saccharine exudation from the bodies of the insects called *Aphides*. The *jelly-dew* is believed to be the original form of a cryptogamian vegetable production, the *Tremella nostoc* of Linnæus; a membranous, pellucid, greenish-yellow matter, about one or two inches in width, which is at first moist and soft to the touch, but dries into a blackish membrane."

SUBSECTION 5.—*White or Hoar-Frost.*

This is nothing more than dew congealed. Both must, therefore, be produced by the same cause, but the condensation of vapor must always precede the formation of hoar-frost. Though it is most frequently observed during the cold mornings of spring and autumn, yet it also occurs in the summer months of even mild climates. It may be produced when the temperature of the air is not sufficiently low to congeal water. As dew is formed on those bodies only which radiate freely, they may be reduced so low as to freeze the water which has been condensed. But even when hoar-frost is formed at a temperature below 32°, it may not remain below this point more than a few hours. The formation of this aqueous meteor is no doubt regulated by the same conditions as that of dew. While the wide-spread plain exposed to the sky is covered with a hoary vesture of whiteness, not a single crystal is found to glitter upon a leaf of the little patch of verdure beneath the protection of a tree or even a shrub.

SUBSECTION 6.—*Mists or Fogs.*

Like the preceding phenomena, these are explainable on the same theory, under whatever circumstances they may occur. They are more frequent in the day than in the night, and in cold than in hot climates; and on the sea, they are generally more stationary than on the land. One of the most extraordinary stationary fogs is found over the Banks of Newfoundland. Here the warm waters of the Gulf Stream and the warm superincumbent air, are encountered by the cold polar currents with their still colder atmosphere; and this intermingling of aërial currents at different temperatures causes in the mixture a diminished capacity for moisture; and consequently a portion of its vapor is deposited in the form of mist. When the cold producing this condensation is very intense, a deposition of minute particles of ice, instead of mist, may take place, covering with delicate crystallizations the twigs and branches of trees, and the hair and clothes of the traveller.

Dense mists or fogs sometimes hang over large cities. In London scarcely a winter passes without the occasional appearance of this phenomenon. It is then enveloped in a dark cloud, like that which shrouds a country during the terrible scenes of volcanic activity; and so impenetrable is this darkness that the daily pursuits of life are suspended, while the environs of the city may have, at the same time, a sky unobscured by a cloud. The same has happened to Paris; as, for instance, the fog of November, 1797, described by Fourcroy, when men in midday came in contact with each other with torches in their hands. In 1790, Amsterdam was enveloped in so dense a fog that upward of two hundred persons, who chanced to lose their paths, were drowned in the canals. These fogs have an explanation similar to that of other aqueous fogs. As the air of the town which may be near the point of saturation, has a higher temperature than that of the surrounding country, the phenomenon may be produced either by the radiation of its own heat, or by the sudden admixture of cold atmospheric currents. The "Dry Fogs," which have been known to spread as a haze over extensive countries, will be noticed in a subsequent paragraph.

SUBSECTION 7.—*Clouds.*

From mists and fogs there is an easy and a natural transition to clouds, which are nothing more than masses of visible vapor, precisely similar in composition, but differing in structural arrangement. The fogs formed at the surface of the earth, over damp ground or in the bottom of valleys, on hills or around elevated peaks, become, when carried off by winds, so many clouds, modified, as they rise into the higher regions of the atmosphere, by the intermixture of strata of different temperatures and in different states of saturation. That clouds have a vesicular structure is now almost universally acknowledged. On the Alps, Saussure saw a multitude of small globules, resembling soap-bubbles, floating before him, being generally about the size of a pea, and seemingly covered with an inconceivably thin coating; and these vesicles, he regarded as the component parts of a cloud. The same phenomenon, the vesicles being only much smaller, has been witnessed by the author in crossing the Alleghany chain in Pennsylvania. These particles, it is believed, are charged with electricity of the same name; and as they thus repel each other, they are prevented from assuming a liquid state and falling as rain. It has, indeed, been proved by the experiments of Volta and Cavallo, that in the process of evaporation, not only is caloric absorbed, but electricity is also developed, the vapor acquiring positive electricity, while the remaining fluid possesses the opposite electric state. Much electric fluid is thus carried into the atmosphere; and when, in the upper regions of the air, a partial condensation of the vapor diminishes its capacity for electricity, it is not improbable that the spherules of vapor may become surrounded with atmospheres of electric fluid; and thus the mutual repulsion of the particles of vapor may prevent their coalescing into drops so heavy as to descend by their gravity to the earth,—an inference favored by the fact that a stratum of air charged with moisture is specifically lighter than dry air at the same temperature. There is still, however, much to be learned in relation to clouds; and in order to be enabled to explain their diversified phenomena, it is necessary to accumulate all the data in our power in reference to the proper-

ties of vapors, as well as the composition, form, color, extent, and elevation of clouds.

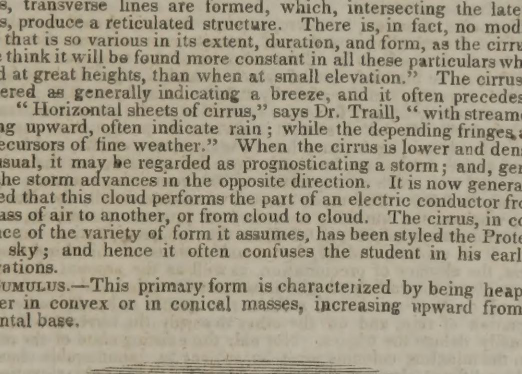
Notwithstanding the endless diversity of figure and appearance presented by clouds, a classification has been adopted by which meteorologists are enabled to compare their observations and results. The system of nomenclature here adopted is that proposed by Mr. Luke Howard, who divides them into three primary forms and four modifications. The three primary forms are:

1. CIRRUS.—This cloud resembles a feather or a lock of hair, composed of fibrous-like stripes, parallel, flexuous, or diverging, unlimited in their extent or direction.

CIRRUS.

This form of cloud is confined chiefly to the higher regions of the atmosphere. It has less density than any other kind, and is generally formed of white radiated streaks, pencilled on an azure sky; but sometimes, it may be seen stretching over half the horizon. "Its duration," says Higgins, "is as variable as its extent; for, although it will frequently retain the same form for many hours, it does occasionally change its appearance so rapidly as not to be recognized, after a few minutes, as the cloud which was first observed. Its direction is not less various. From the primitive threads which are first woven, others are thrown, some laterally, others upward or downward, some or all becoming in time the branches of new shoots; while, under some circumstances, transverse lines are formed, which, intersecting the lateral threads, produce a reticulated structure. There is, in fact, no modification that is so various in its extent, duration, and form, as the cirrus; but we think it will be found more constant in all these particulars when formed at great heights, than when at small elevation." The cirrus is considered as generally indicating a breeze, and it often precedes a storm. "Horizontal sheets of cirrus," says Dr. Traill, "with streamers pointing upward, often indicate rain; while the depending fringes are the precursors of fine weather." When the cirrus is lower and denser than usual, it may be regarded as prognosticating a storm; and, generally, the storm advances in the opposite direction. It is now generally believed that this cloud performs the part of an electric conductor from one mass of air to another, or from cloud to cloud. The cirrus, in consequence of the variety of form it assumes, has been styled the Proteus of the sky; and hence it often confuses the student in his earlier observations.

2. CUMULUS.—This primary form is characterized by being heaped together in convex or in conical masses, increasing upward from a horizontal base.



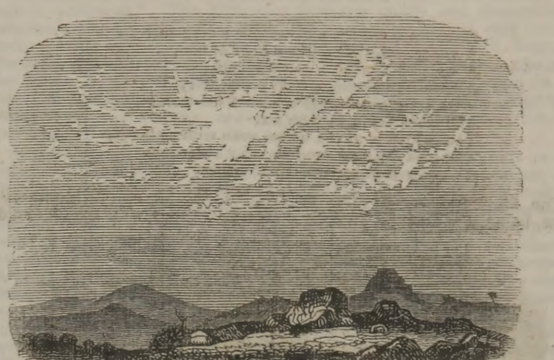
CUMULUS.

The cumulus is generally a dense hemispherical cloud moving near the surface of the earth. In fair weather, it has a well-defined rounded surface. Beginning in the morning, it obtains its greatest magnitude about 2 P. M., and usually decreases before sunset, breaking up and disappearing before nightfall. When it is the harbinger of rain, it increases rapidly in size, mass rolling upon mass like Pelion upon Ossan, the whole presenting the appearance of a vast aërial mountain scene. Its dense masses, which are now nearer the surface of the earth than usual, present, instead of a rounded surface, a fleecy appearance. Speaking of this modification of clouds, Mr. Howard makes the following remarks:—"Independently of the beauty and magnificence it adds to the face of nature, the cumulus serves to screen the earth from the direct rays of the sun; by its multiplied reflections, to diffuse, and, as it were, to economize the light; and also to convey the product of evaporation to a distance from the place of its origin. The connection of the finer round forms, and more pleasing dispositions and colors of these aggregates, with warmth and calmness; and of everything that is dark, and abrupt, and shaggy, and blotched, and horrid in them, with cold, and storm, and tempest, may be cited as no mean instance of the perfection of that wisdom and benevolence which formed and sustains them."

3. STRATUS.—This cloud spreads horizontally in a level, continuous, and wide-extended sheet, increasing from below. It is the lowest of all clouds, being often seen, in calm evenings, creeping along the ground, near lakes and rivers, and rising toward the higher grounds. At night, it often travels over plains and invests the summits of moderate elevations, and usually melts away before the morning sun, after being gradually separated from the earth. The stratus has been long known as the harbinger of fair weather, the day ushered in by it being almost invariably serene and cheerful.

Of the four modified forms of clouds, two are intermediate and two are composite. Of the former, the first is the—

CIRRO-CUMULUS.—This modification consists of small, well-defined, roundish masses, arranged in close horizontal order or contact. The



CIRRO-CUMULUS.

cirrus here appears to lose its fibrous character, its streaks seeming to contract and form themselves into globular masses,—an alteration of form supposed to result from the cessation of its function as the electrical conductor of the atmosphere. Sometimes the sky, on a fine summer's evening, is nearly covered with the nubeculæ of the cirro-cumulus, while at other times these well-defined and roundish masses are widely separated. It is usually a prognostic of fine weather, except when it accompanies the cumulo-stratus; and then it is the harbinger of a storm.

The *Cirro-Stratus* forms the other intermediate modification. The masses composing this form are likewise small and rounded, being attenuated toward a part or the whole of their circumference: when in groups, their arrangement is either horizontal or slightly inclined, and their masses are either undulated or bent downward. It often changes

CIRRO-STRATUS.

its form. It has a uniform hazy appearance when seen overhead; but viewed on the horizon, as it is here presented edgewise, it often seems very dense. When it is stationary, it indicates rain or storms of snow. As the halo appears most frequently in this species of cloud, it is hence, in all probability, as Mr. Howard suggests, that this phenomenon has come to be regarded as a prognostic of foul weather. The cirro-stratus often envelopes mountain summits, and descends, in cold weather, into plains as soaking dense mist.

Of the two compound modifications of clouds, the first is designated the—

Cumulo-Stratus, which is made up of the cirro-stratus blended with the cumulus, the former either intermingling with the larger masses of the latter, or superadding a wide-spead structure to its base. As this modification is a compound of those clouds which indicate fair, as well as those which bring unsettled weather, it is not unusual in those countries which are subject to atmospheric vicissitudes. Hence its indications are not uniform. This cloud, ever-varying in its forms, often

assumes a portentous size, in which the imagination may picture in bold outline, its wildest vagaries.

CUMULO-STRATUS.

Sometimes we see a cloud that's dragonish;
A vapor sometimes, like a bear or lion,
A towered citadel, a pendent rock,
A forked mountain, a blue promontory,
With trees upon't that nod unto the world
And mock our eyes with air.
That which is now a horse, even with a thought
The rack dislimns, and makes it indistinct
As water is in water.—SHAKSPERE.

The *Cumulo-Cirro-Stratus*, or *Nimbus*, is the second composite form, being a horizontal stratum of aqueous vapor, over which clouds

CUMULO-CIRRO-STRATUS, OR NIMBUS.

of the cirrous form are spread, while those of the cumulous form enter it laterally and from beneath. This is the cloud or system of clouds, from which rain falls. It has its origin generally in the cumulus. Previous to the fall of rain, vast masses of cumuli may often be seen rising into towering aërial mountains, and taking imperceptibly the structure of the cumulo-stratus; and this modification, becoming more dense, and increasing, at the same time, in extent and irregularity of figure, soon forms itself into the nimbus or rain-cloud. Although the cumulus and cumulo-stratus frequently assume a darker and more threatening aspect, yet no cloud is so readily distinguished as the nimbus or cumulo-cirro-stratus. This cloud, which is always in an electrified condition, is never absent during a thunder-storm; and then its dark and apparently compact structure, as the electric fluid darts from cloud to cloud, or cleaves its way to the earth, seems to be rent by the terrific violence of this mysterious power.

As regards the *motion* of clouds, it may be remarked that a more frequent subject of optical delusion is perhaps never presented. This is well illustrated in the following extract from Prout's Bridgewater Treatise:

"Let us suppose a cloud moving from the distant horizon toward the place where we stand. Let us also suppose that the cloud during its motion retains the same size and figure, and that it proceeds along its course in a uniform horizontal line. A cloud so moving, when first seen, will appear to be in contact with the distant horizon; and will thus necessarily, from its remote position, appear to be much smaller than in reality it is. During its advance toward us, the cloud will seem to rise into the sky, and to become gradually larger, till it is almost directly overhead. Continuing its progress, it will then seem again to descend from the zenith, and to lessen in size as gradually as it had before increased, till at last it vanishes in the distance, opposite to where it commenced its movement. Thus the same cloud, without deviating from its motion in a straight line, and retaining throughout the same size and figure, will, by optical delusion, seem continually to vary in magnitude. The line of its motion also, instead of being straight, will appear to be a curve having its vertex directly above us, and its extremes boundless in opposite points of the horizon. We have given the most simple case that can be supposed. But clouds, as they exist in nature, are unceasingly varying in shape, in magnitude, in direction, and in velocity; so that to form a just estimate of their figure and direction, or to unravel their motions, becomes absolutely impossible."

The uses of clouds in the economy of nature are almost without number. Water is thus transported from the ocean to inland countries, which would otherwise suffer from deprivation. As they greatly mitigate the extremes of temperature, clouds are of vast benefit to extra-tropical countries. By day, they not only produce the agreeable vicissitude of shade and sunshine, but protect vegetation from the scorchin influence of solar heat; and at night, the earth wrapt in its mantle of clouds, retains the caloric that it would otherwise lose by radiation, causing an extreme of temperature prejudicial to vegetation.

Having completed the consideration of the various states of visible vapor, it remains to examine the phenomena of the precipitation of water from the atmosphere in the form of *Rain, Snow, Sleet, and Hail.*

SUBSECTION 8.—*Rain.*

As rain has its origin from the clouds, no theory of its production will be entirely satisfactory, until their formation shall be clearly understood. This subject, like many others in meteorology, will, doubtless, be relieved from many of its perplexing circumstances, when we come to be better acquainted with the influence of electricity upon the conditions of atmospherical phenomena. Among the numerous speculations relative to the production of rain, one of the most ingenious is that proposed by Dr. James Hutton. Rain, according to this hypothesis, results from the intermingling of extensive strata of air saturated with moisture at different temperatures. From the law of the elastic force of vapor, already described—that temperatnre and solution do not increase by equal increments—it follows that when two atmospheric currents of different temperatures, but equally saturated with vapor, are mixed together, notwithstanding the resulting temperature of the mixture will be the mean of the two, the resulting force of the vapor will exceed the tension belonging to the resulting mean temperature. This theory has been so well illustrated, in an excellent paper in the Encyclopædia Metropolitana, by Mr. Harvey, that a quotation here will not be considered out of place. "Let it be required to mingle two volumes of air, of the temperature of 40° and 60°, each being saturated with humidity. The force of vapor at these temperatures is known to be respectively 0.263 and 0.524 inches of the mercurial column. The compound mixture will evidently have a mean temperature of 50°, and the mean of the elastic forces is at the same time 0.393 inches of the same column. But if we now inquire whether air at the temperature of 50° requires an elastic force of this last mentioned magnitude to saturate it entirely with vapor, we shall find that it does not; and that, at the mean temperature here referred to, the measure of entire saturation is really 0.375 inches of quicksilver. The difference of the two columns, or 0.018 inches of mercury, is hence the amount of moisture that must be precipitated in some way or other from the compound mass.

"To prove, moreover, that this precipitation cannot be constant for equal differences of temperature, let us further take the example of the temperatures of 60° and 80°. In this case we shall find the elastic forces to be 0.524 and 1.000; and that at the mean temperature of 70°, the force of vapor is 0.721 inches. But the mean of the two elastic forces 0.762, thereby proving that a quantity of vapor corresponding to 0.041 inches of the mercurial column, must be discharged the moment the aerial volumes are united.

"The order of nature, however, requires that rain should not always result from the mingling together of opposite currents, and the theory before us amply confirms it. Two volumes of the temperature of 50° and 60° may be blended, one of which contains vapor denoted by 0.2 inches of mercury, and the other by 0.3, the mean being 0.25; whereas, the quantity necessary for entire saturation, at the mean temperature of 55°, is 0.443. In such a case, it is obvious no precipitation can take place. One volume, again, may have a temperature of 52°, and be in a state of entire saturation, its elastic force being 0.401; but the volume to be united to it, with a temperature of 70°, containing moisture equivalent only to 0.589. The mean amount of moisture will, therefore, be 0.495; whereas, the humidity necessary to produce saturation, at the mean temperature of 61°, is 0.542, so that no precipitation can take place. It is evident, indeed, that combinations of this kind may be endless, the absence of precipitation, as well as the amount of it when it takes place, depending on circumstances so varied and uncertain, as to afford, on the one hand, a shower so gentle as hardly to bear the designation of rain, and on the other to supply the torrents which occasionally deluge the tropics. Not only the existing state of the moisture in the mingling columns must be subject to innumerable changes, but their different degrees of heat must be altered also; the elevation of their mean temperature, too, as well as the extent of combination which takes place among all the moving volumes, must impress necessarily upon the whole of the phenomena the greatest diversity."

It must, however, be admitted that the subject of the general condensation of moisture from the atmosphere, is still involved in considerable obscurity. It was early shown by Sir John Leslie, that, although a deposition of moisture or of rain will follow from the causes above stated, yet the effect produced would be less than what is often observed to take place, unless two currents of air may be supposed to be moving rapidly in opposite directions. Now as heavy falls of rain are not unfrequently witnessed when the clouds emitting it can scarcely be observed to move, it follows that some additional cause must be in operation. When treating of the formation of clouds, their suspension in the atmosphere was ascribed to the repulsions among the electric atmospheres of their particles. Now if we suppose this electric fluid to be withdrawn at the same time that the commingling of currents, above described, takes place, the theory of rain seems more satisfactory. When rain is not accompanied either by thunder or lightning, the electric fluid appears to be slowly withdrawn; while the phenomena of lightning and loud thunder would indicate a great accumulation of electricity, and its sudden explosion. This view is favored by the circumstance that any considerable electric discharge from the atmosphere is generally accompanied by a fall of rain, and that the quantity usually is in proportion to the violence of the thunder-storm. Moreover, the opinion that evaporation is the grand source by which the atmosphere acquires electricity, is warranted by the fact that the effects of this agent are displayed more energetically in proportion as we proceed from the equator toward the poles.

The mean annual evaporation and condensation over the globe would appear, at first view, to bear a close relation to the mean temperature, and consequently to the latitude. That the average qua

of rain diminishes from the equator to the poles, is a general law; but the quantity varies so much, from local or other causes, that the exceptions are more numerous than the instances of the correctness of the rule. A much larger quantity, however, must fall in the equatorial than in the polar regions, of which evidence is afforded in the magnitude of the rivers within the tropics; for as rivers are the conduits along which a certain portion of the precipitated water is transported to the sea, their size may be regarded as an index of the mean annual quantity of rain. The following table as given by Prout, notwithstanding the progression exhibits great irregularity, fully establishes the general law of the decrease of rain with the increase of distance from the equator:—

	Inches.
Uleaborg,	13.5
Petersburg,	16,17.5
Paris,	19.9
London,	*20.7, †22.2, ‡25.2
Edinburgh,	22, 24.5, §26.4
Mean of Carlsruhe, Manheim, Stuttgart, Wurtzburg, Augsburg, and Regensburg, (Schow)	25.1
Epping,	27,0
Bristol,	29.2
England, (Dalton's mean.)	31.3
Liverpool,	34.1
Manchester,	36.1
Rome,	39 0
Lancaster,	39.7
Geneva,	42.6
Penzance,	44.7
Kendal,	53.9
Mean of 20 places in the lower valleys at the base of the Alps,	58.5
Great St. Bernard,	63.1
Vera Cruz,	63.8
Keswick,	67.5
Calcutta,	81.0
Bombay,	82.0
Ceylon,	84.3
Adam's Peak,	100.0
Coast of Malabar,	123.5
Leogane, St. Domingo,	‖150.0

The annual quantity of rain, it thus appears, diminishes with the latitude; but there are powerful local modifying causes, which will be presently brought under notice.

It has been computed by Sir John Leslie, that if all the aqueous vapor which the whole atmosphere is capable at any time of holding in solution, were precipitated on the earth at once in the form of rain, it would not exceed five inches in depth. Now, as the mean annual fall of rain over the globe is not less than seven times this quantity, it follows that it must be replenished as many times by evaporation. An important question is presented in the relative mean evaporation and condensation. As regards the mean annual evaporation, some interesting experiments were performed by Dr. Dalton and Mr. Hoyle, at Manchester, England, in 1796, 1797, and 1798. A cylindrical vessel of tinned iron, three feet deep and ten inches in diameter, having one pipe near the bottom and another one inch from the top, was filled with soil; and in this condition it was left for a year, when it had become covered with grass. Bottles being now attached to the end of each pipes, the surplus water which soaked through the earth, and that which ran off at the upper pipe, were both collected. On commencing the experiment, the soil was soaked with water. A rain-gauge of dimensions similar to that of the cylinder being placed near it, the amount of evaporation was estimated by subtracting the quantity which passed into the bottles from the whole rain. Thus in—

	1796.	1797.	1798.
Rain	30.629 inches.	38.791 inches.	31 259 inches.
Evaporation	23.725 "	27.857 "	23.862 "

giving 25.148 inches for the mean annual evaporation, and 33.559 inches for the annual condensation, at Manchester; but to this, in the opinion of Dr. Dalton, there ought to be added five inches for the annual dew, thus making the total annual evaporation about thirty inches. As the mean annual evaporation is generally estimated at thirty-four inches, the whole mass of water raised by this process from the surface of the earth is equal to 105,614 cubic miles, which is the estimated quantity annually precipitated on our globe. These calculations, however, are nothing more than rude approximations. In different countries, although the relative proportion of water evaporated, and of the water condensed, must necessarily vary exceedingly, yet it is probable that in the same country, these proportions exhibit little variation. As a large proportion of water condensed on the land, must have been evaporated from neighboring seas, it follows that in countries which discharge superfluous waters into the ocean, condensation must exceed evaporation.

There are many causes which exert a powerful influence upon the annual fall of rain; such as, its position in relation to the equator, its proximity to the sea and its elevation above its level, as well as the exposure of the place, and the mountains, woods, &c. in the vicinity.

It has been already shown that the mean annual quantity decreases from the equator to the poles. The following table, according to Humboldt, exhibits the proportional quantity of rain in different latitudes:

Latitude.	Mean annual quantity of rain.
0°	96 inches.
19	80 ,,
45	29 ,,
69	17 ,,

Although in the table given above we find the annual quantity, from Uleaborg, Lapland, to St. Domingo, varies from 13 5-10 to 150 inches, yet there is no regular average throughout a parallel. While in some places it seldom or never rains, as in the Great Desert of Africa, and on the arid shores of Peru between the 15° and 30° of lat.; there are, on the other hand, regions in which rain is almost constantly falling. In the British Possessions on the western coast of Africa, for example, upward of 300 inches of rain, according to the British army statistics, have frequently fallen during the "wet season" alone. Upon the sea, a less quantity falls than upon the land, as the former has no elevations around which clouds may be attracted. As the augmented quantity in tropical countries falls at a particular season and in a shorter space of time than in colder regions, the annual number of dry days is proportionally increased. Hence the humidity of any climate cannot be inferred from the annual quantity of rain, inasmuch as the number of rainy days is generally least where the fall of rain is greatest. A region remarkable for a low annual ratio of rain, may be involved in almost perpetual fogs, or have many days of drizzling rain.

On seacoasts, rain falls more abundantly than in inland localities, notwithstanding they may both have the same physical features. This has been explained on the ground that the atmosphere in the vicinity of the sea has greater humidity; and hence it is more liable to have its moisture precipitated.

The quantity of rain is also much influenced by the vicinity of mountains. "Mountains," says Higgins, "when acted upon by the sun, heat the air which is in contact with them, even in the cold regions of the upper atmospheric strata. These heated masses of air absorb the moisture from the colder columns around; but, meeting with humid masses of lower temperature, or cooled by the constant abstraction of their heat, the humidity becomes too great for the temperature, and rain is produced." The difference between plains and mountainous countries is so great, that, at Paris, the annual quantity is only twenty inches, while at Geneva, it is 42½ inches, and on the Great St. Bernard, the highest meteorological station in Europe, it is 63 inches. Again, in the Julian Alps, the annual fall is estimated at 100 inches, while in the valley of Lombardy, it does not exceed 35 inches; and so of Demerara, in the swamps of Guiana, and of the lofty island of Granada, the former being 97 and the latter 126 inches.

In most tropical countries, rain falls only at particular periods of the year. At Bombay, for example, June, July, August, September, and October, are the rainy months, an unclouded sky being presented the rest of the year; but on the opposite side of Hindostan, on the Coromandel coast, the period of the rainy season is reversed,—a result attributed to the high intervening table-land, which is supposed to influence the atmospheric currents. Wherever the atmosphere experiences a periodical change in the direction of its currents, periodical rains occur. During the steady prevalence of the trade-winds, rain is a very uncommon occurrence; for, on account of the uniformity of temperature, no condensation can take place, the aqueous vapor being carried upward and steadily moved onward. But no sooner do these great currents, following the course of the sun, commence to shift their direction, than heavy rains begin to fall; for as currents of different temperatures now become intermingled, condensations of moisture, commensurate with the high temperature, are produced. It is during the shifting of the monsoons, that the heavy rains of India fall. Even in the temperate climate of England, it has been long observed that a dry season is always accompanied by a wind of remarkable uniformity, while a variable and an unsteady motion of the atmosphere as constantly attends a wet season. In tropical climates, the phenomenon of a periodical descent of rain is even often produced daily by the land and sea breezes. While masses of water which afford a large evaporating surface, cause a great abundance of rain in certain regions; there are, on the other hand, as already remarked, certain situations in which there is an absence of all precipitation, as in the Sahara of Africa, on the low coast of Egypt, and a portion of the coast of Peru. As a uniform wind must produce constant precipitation or no rain at all, the permanency of the result will depend on the permanency of the cause. As the prevailing wind, for example, on that part of the coast of Peru just adverted to, passes from a colder into a warmer region, there can be no precipitation, because its capacity for moisture continually augments.

As regards the seasons, the greatest amount of rain falls when the mean monthly temperature is highest; but, although the quantity is greater in summer than in winter, the latter exhibits the greater number of rainy days. Rain falls in greater abundance during the day than the night.

The drops of falling rain vary in size from 1-25th to 1-3rd of an inch in diameter: and their ultimate velocity, it has been calculated, is in the duplicate ratio of their diameters. To ascertain the quantity of rain that falls in any place, various kinds of instruments, known by the names of *udometers*, *ombrometers* or *rain-gauges*, have been employed. It is not, however, deemed necessary to give a description of them. In regard to the proper position of a rain-gauge, some practical difficulties are presented, in consequence of the fact now repeatedly verified, that the mean annual quantity of rain is less in proportion as the receiving vessel is elevated above the surface of the earth. This result, as it follows uniformly, cannot be referred to accidental circumstances. The experiments made at the Royal Observatory, at Paris, during a period of fourteen successive years, as well as at Yorkshire, England, establishes the fact beyond all doubt. The mean annual quantity falling at Paris, in the court of the Observatory, is 56 centimetres, while at an elevation of 28 metres above this point, on the roof of the building, the mean quantity is only 50 centimetres. It was satisfactorily ascertained that even a difference of only five or six feet, affected the annual result in a sensible degree. These differences, which are fully confirmed by the experiments at Yorkshire, may be attributed, in a great measure, to the circumstance that each drop of rain, in its passage through the atmosphere, augments, on the principle of condensation, in proportion as it approaches the surface of the earth.

It is necessary to determine not only the mean *annual*, but also the mean *monthly* quantities of rain, inasmuch as the latter results have a more direct relation with vegetation.

The "directions" at our military posts, at all of which the conical rain-gauge is used, are as follows:—"It will be kept remote from all elevated structures, to a distance at least equal to their height, and still further off, where it can be conveniently done. It is to be suspended in a circular opening made in a board, which is to be fixed to a post, eight feet from the ground; the opening to be five inches diameter, and bevelled, so as to fit the side of the gauge, into which the cap is to be fixed, base downward, to prevent evaporation. * * * In freezing

* Dalton. † Daniell. ‡ Howard. § Adie.

‖ From the Encyclopædia Metropolitana. Article Meteorology, p. 123.

weather, when the rain-gauge cannot be used out of doors, it will be taken into the room, and a tin vessel will be substituted for receiving the snow, rain, or sleet, that may then fall. This vessel must have its opening exactly equal to that of the rain-gauge, and widen downward to a sufficient depth with a considerable slope. It should be placed where nothing can obstruct the descending snow from entering, and where no drift snow can be blown into it. During a continued snow-storm, the snow may be occasionally pressed down. The contents of the vessel must be melted, by placing it near the fire, with a cover to prevent evaporation, and the water produced poured into the gauge to ascertain its quantity, which must then be entered on the register."

SUBSECTION 9.—*Snow.*

In regard to the formation of this substance, our knowledge is limited; but in respect to the different forms of crystallization which the flakes assume, our observations are more complete. When carefully examined by a microscope, flakes of snow are found to consist of a mass of beautiful crystals, more or less perfect and regular. These appearances were first described in 1740 by Dr. Nettis of Middleburgh; but it is to Captain Scoresby, who availed himself of the opportunities for its investigation presented in his polar voyages, that we are chiefly indebted for our knowledge on this interesting subject. His work contains the delineations of about 100 very curious and remarkable figures; but it were foreign to the object of this work to detail his results. Modifications or combinations of the hexangular prisms, often consisting of a star of six rays, formed of prisms united at angles of 60°, are exhibited by these flakes, the whole having a plumose appearance of exquisite beauty.

The quantity of snow which falls in any place is regulated by its climate, as depending on latitude, elevation, and position. In the polar regions, according to Mr. Scoresby, it snows nine days out of ten during April, May and June, the heaviest falls occurring when a moist current from the sea encounters a cold breeze from the surface of the ice. During the most inclement season, when the inhabitants of these inhospitable climes have immured themselves in their huts, it is necessary, he says, to prevent the admission of the cold air by stopping up every crevice, or otherwise the vapor of the confined air would be immediately precipitated as snow.

As snow is a bad conductor of caloric, it shields vegetation and preserves the seeds intrusted to the earth, from the rigorous cold of the higher latitudes—a property well known to the husbandman from time immemorial; but it is only since the successful investigations of Dr. Wells in regard to dew, that science has been able to afford a satisfactory explanation. It not only prevents the loss of terrestrial heat by radiation, but defends the surface from the frigorific influence of very cold winds. That the air is warmer during a fall of snow, than before or after, is a well known fact, which is attributable to the extrication of heat in the sensible form during the transition of the vapor from a fluid to the solid state. Another striking instance of design on the part of Nature, is exhibited in the laws of atmospheric temperature as regards snow and ice; for, were these laws the same as we observe in other bodies, every country liable to snow and ice would be annually destroyed by inundation. In the liquefaction of ice, as already shown, 140° of caloric become inappreciable by the thermometer; and hence, were not this immense quantity of caloric rendered latent in the liquefaction of snow, the greatest accumulation would at once be converted into water as soon as the atmosphere should rise above the temperature of 32°.

There are also what are called *frost-smoke*, *spicular snow*, and *sleet*. The first, which is not unfrequently witnessed in polar latitudes, consists of frozen particles of water, which float in the atmosphere in the form of crystallized spiculæ. The second, which is supposed to have its origin in causes similar to those which produce snow, is composed of minute needles, grouped and intermingled so as to have the appearance of a delicate *bouquet*. Sleet, which is the thin transparent layer of ice, frequently observed in winter covering the surface of the earth and other objects, is formed by rain which freezes as it falls upon the ground.

SUBSECTION 10.—*Hail.*

As these phenomena, so formidable to the interests of the husbandman, is of very frequent occurrence in the south of France, the subject has been very closely studied by the philosophers of that nation.

Hail seems to be the production of sudden and intense cold in the higher regions of the atmosphere; and hence a fall of hail is not uncommon in warm climates, in which snow is utterly unknown. These *frozen balls* or *hail-stones* exhibit great variety as regards form and size. The ordinary size varies from 1-10th to 1-3rd of an inch in diameter; but occasionally they are much larger, being three or four inches in diameter, and weighing from ten to thirteen ounces. In June, 1811, an enormous hail-stone fell during a storm, in England, which measured 6½ inches in diameter, having the appearance of a congeries of frozen balls about the size of walnuts. As the icy nucleus doubtless has a temperature far below the freezing point, the hail must necessarily acquire magnitude as it descends, by condensing on its surface the vapor of the lower regions of the atmosphere. Hence they are always more or less rounded, and composed of concentric layers. Notwithstanding it usually hails but a few minutes, extending very rarely to a quarter of an hour, the quantity of ice which falls is so great as frequently to cover the ground to the depth of several inches. A hail shower is often ushered in by a peculiar rattling noise, which has been compared to the sound produced by a number of bags of nuts suddenly emptied together on a floor. The clouds that bring hail have a remarkably ashy color, and are little elevated in the atmosphere; and they are of great extent, with rugged edges and enormous protuberances on the lower surface. Hail is sometimes accompanied with thunder; and it generally precedes the rain of a storm, and is sometimes mingled with it. It is most frequently formed in the spring and summer, and during the warmest part of the day. In winter or during the night, it seldom hails.

So great is the fury of hail-storms in France that whole districts are sometimes laid waste; and these calamitous visitations are usually accompanied by whirlwinds and the most terrific electrical phenomena. And here the hail-stones have often an irregular shape, being angular masses of many pounds in weight, as though they were fragments of a thick sheet of ice. To guard against these destructive visitations, the ingenious device of the *Paratonnerre* has been used in France,—a contrivance which consists in the erection of pointed electric conductors on the surrounding hills, with the view of abstracting the electricity silently and gradually from the air, and thus prevent those dangerous accumulations over the included districts. "In hot climates," says Dr. Traill, in the Encyclopædia Britannica, "the descent of large masses of frozen water is still more common than in Europe, especially within the *calms* off the western coast of Africa."

The celebrated Volta accounts for the first formation of hail in the following manner:—"The clouds are formed of hollow vesicles, the external surface of which is fluid. The myriads of these, which form the upper surface of a cloud, must undergo, toward the south, a strong evaporation, both on account of the intensity of the solar rays and the dryness of the air in which they swim. The elastic vapor thus produced by the solar heat must first saturate the dry air through which it passes, and at length, by the low temperature of some superior stratum, become again reduced into a vesicular state, forming another cloud, differing in its electrical condition from the first. The upper cloud will have positive electricity, on account of that species of electricity being developed during the precipitation of vapor, the lower having changed its character to negative, in consequence of the evaporation it has undergone. A diminished temperature at length may produce, between the clouds, icy particles, or hail in a nascent state, which the opposite electrical states of the upper and lower clouds will cause to oscillate, until, by gathering matter from the surrounding moisture, they become at length enveloped in compact and opaque ice, and attain a size which, overpowering the electric forces, compels them by gravity to descend."

The most powerful argument against this theory is that urged by M. Arago, who asks how it is that the clouds, which may be supposed to attract each other as well as the hail, are not brought together. But no theory has so far embraced all the phenomena. A satisfactory explanation requires in the first place a knowledge whence the cold arises, by which the nucleus of each ball of hail is produced; in the next place, a knowledge of the process by which these balls augment in size; in the the third place, a knowledge of the force which sustains in the atmosphere masses of ice, weighing sometimes a pound or more, (but, as already observed, they may form as they fall, and fall as they form;) and, in the last place, a knowledge why electrical phenomena are so energetic, passing rapidly from one state to another, whenever the sky exhibits those low, rugged, swollen, and ash-colored clouds, which announce the impending hail-storm. The theory of Mr. Espy in regard to the formation of hail and several other atmospheric phenomena, will be noticed in the sequel.

All the preceding phenomena which belong to the precipitation of water from the atmosphere viz., *Dew, Fogs, Clouds, Rain, Snow, and Hail*, have a close relation with one another, depending no doubt on some general fundamental cause; and to arrive at a theory satisfactory in every point of view, further research is demanded.

SECTION V.—WINDS IN GENERAL.

In continuation of the *accidental* phenomena pertaining to meteorology, the extensive and complicated subject of winds will now be brought under examination.

Whatever disturbs the equilibrium of the atmosphere produces wind; and as the most important of these disturbing causes is the action of the sun, winds are produced chiefly by that law of fluid matter which compels the atmosphere to seek its level in obedience to the attraction of the earth. Atmospheric currents may be considered under two heads: the first being of a general character, extend over the whole globe; and the second being of a local nature, arise from a great variety of disturbing causes in physical geography, as influencing the equal distribution of heat over the surface of the globe, or modifying the hygrometric and electric states of the atmosphere.

The *general currents* of the atmosphere depend principally upon the unequal temperature of the poles and the equator, in connection with the earth's diurnal motion upon its axis. As the mean annual temperature in the vicinity of the equator, at the level of the sea, is upward of 80°, while in the polar regions it is constantly below the freezing point of water, 32°, and as the entire pressure of the atmosphere, at the level of the sea, is the same over all the earth's surface, being equivalent to that of a column of mercury about thirty inches in height, it follows, to maintain this equilibrium, that two grand currents will be in perpetual motion. As a given bulk of air at the level of the sea in the polar regions, must consequently be specifically heavier, than a similar volume at the level of the sea under the equator, it is obvious that the dense cool air of the polar and temperate regions naturally tends to take the place of the more rarefied air over inter-tropical regions, which, owing to its lightness, ascends and flows back again over the colder stratum, north and south toward each pole, so as to preserve the equilibrium. Thus are established two currents, a polar and an equatorial, which, being as permanent in their operation as the causes that produce them, constitute one primary element of the winds—phenomena of the utmost importance in the economy of nature, as tending to equalize the distribution of temperature over the surface of the globe.

The other primary element of the winds is the result of the earth's diurnal motion upon its axis. If the earth were at rest, and its surface a plain, the northern hemisphere would, of course, experience a constant north wind, and the southern hemisphere a constant south wind; but as the earth is in an unceasing state of motion upon its axis from west to east, these currents are deflected from their northern and southern course, producing an easterly current in the atmosphere. The velocity of every point on the earth's surface, in its diurnal rotation, increases from the poles to the equator, the ratio of which, according to Captain Basil Hall, is as follows:

0° - - -	1000 miles.	50° - - -	640 miles.
10 - - -	985	60 - - -	500
20 - - -	940	70 - - -	342
30 - - -	866	80 - - -	174
40 - - -	766	90 - - -	0

Thus while the velocity of any point on the equator is about 1000 miles an hour, the poles are quiescent; and from this extreme, the rate of motion gradually increases until it attains its maximum at the equator. The under-current of air from the polar regions to the equator, is consequently influenced by a force acting at right angles to that which

results from the rarefaction of the atmosphere at the equator; for as the particles of these currents cannot acquire a velocity equal to the continually accelerating rotary motion from west to east, they will gradually seem to acquire a motion in a direction opposite to that of the rotation of the earth. Impressed by two forces, these currents take an intermediate path, describing a curved line with its convexity toward the east; and thus, by gradually declining to the west, assume in the northern hemisphere the character of a N. E., and in the southern, of a S. E. wind. "This effect of the augmenting velocity of the earth's surface," says Dr. Traill in the Encyclopædia Britannica, "in approaching the equinoxial line, is increased by the continual movement of the point over which the sun is vertical, and conseqently his heat the greatest, to the west; and the effect of the gravitation of the sun and moon on the atmosphere, as was shown by D'Alembert, must directly tend to increase the force of the easterly wind. The influence of these luminaries on our atmosphere is corroborated by the observations of Bacon, Halley, and Gassendi, on the frequency of storms about the equinoxes, or at full and new moon, and the general occurrence, in calm weather, of light airs of wind at the time of high water. When these causes are not counteracted by the superior rarefaction of air over land heated by the sun's rays, the easterly winds blow with much regularity, as in the great oceans; and, from their important influence on navigation, they have obtained the denomination of *trade-winds*." These winds extend to about 30° on each side of the equator. At their extreme northern and southern limits, they generally blow nearly due east; but, as the equator is approached, in both hemispheres, these currents, as they gradually acquire the velocity of the earth, finally proceed due north and south. "The reason why the trade-winds," says Dr. Neil Arnott, "at their external confines, which are about 30° from the sun's place, appear almost directly *east*, and become more nearly *north* and *south* as they approach the central line, is, that at the confine they are like fluid coming from the axis of a turning wheel, which has approached the circumference, but has not yet acquired the velocity of the circumference; while nearer the line, they are like the fluid after it has for a considerable time been turning on the circumference, and has acquired its rotatory motion, appearing at rest as regards that motion, but still leaving sensible any motion in a cross direction."

The opinion of a counter-current in the upper regions, distributing the heated air toward the poles, was for a long time merely speculative, but more recently many striking proofs have been noted in confirmation. At the summit of the peak of Teneriffe, for example, repeated observations have proved that there is always a powerful current in a direction contrary to that of the trade-wind on the surface of the ocean below. Another instance is afforded by the fact that the volcanic dust thrown forth from the Island of St. Vincent, has been repeatedly observed by the inhabitants of Barbadoes, hovering over them in thick clouds and falling, having travelled more than 100 miles in a direction opposite to the powerful trade-winds, to avoid which ships take a circuitous course.

This clear and satisfactory theory of the great atmospheric circulation is, in a great measure, due to Mr. Daniell; and this theory was subsequently illustrated by Captain Basil Hall, in his interesting essay on the trade-winds.

Were the surface of the globe one expanse of water, the trade-winds would blow all round the equator, and the only other winds known would probable be N. and S. winds between the poles and tropics, at which point they would gradually bend from E. to W. to form the trade-winds. But, under existing cirumstances, as the atmosphere over the land is much more heated by the sun's rays than over the sea, great interruptions to the regularity of the trade-winds are caused by large islands and continents. On the coasts of Africa, for example, *westerly* gales are not unknown within the limits of the trade-winds; and along the western shores of that continent, from Cape Palmas to the Cape of Good Hope, a *southerly* wind prevails. On this coast from 10° to 4° N., there is a tract remarkable for its *calms*, which, on this account as well as sudden alternations attended with tremendous storms of thunder and lightning, is avoided by seamen. It is on the western coasts especially that the force and direction of the trade-winds are modified. On the western coast of Mexico, between the 8th and 22d degrees of north latitude, a complete inversion of the trade-wind occurs; for here, instead of an easterly current, an almost permanent westerly wind prevails. Moreover, the phenomena are not the same in the two hemispheres, and they are also modified by the seasons. As the northern hemisphere contains more land than the southern, and as the atmosphere of the former is consequently more rarefied, the line which marks the blending of the S. E. and N. E. trade-winds is between two and three degrees north of the equator.

In the Indian Ocean, the trade winds are so much modified by local causes, that they change their direction every six months, constituting the *Monsoons*, so called from a Malayan word signifying *seasons*. As the great continent of Asia lies chiefly north of the equator, the atmosphere over Arabia, Persia, India, and China, during the summer-half of the year, becomes so rarefied as to produce a constant influx of the colder air of the regions south of the equator; but, as soon as the summer of the southern hemisphere approaches, the current gradually changes its direction, and soon rushes toward the more rarefied air of the ocean. This constitutes, in reality, a sea-breeze of six months, and a land-breeze of the same period. This semi-annual change is attended with a remarkable effect on the climate of these countries. It is the harbinger of the rainy season, a most striking picture of which is given by Mr. Elphinstone in his account of Caubul.

"The most remarkable rainy season is that called in India the S. W. Monsoon. It extends from Africa to the Malayan peninsula, and deluges all the intermediate countries, within certain lines of latitude, for four months in the year. In the south of India, this monsoon commences about the beginning of June, but it gets later as we advance toward the north. Its approach is announced by vast masses of clouds, that rise from the Indian Ocean, and advance toward the N. E., gathering and thickening as they approach the land. After some threatening days, the sky assumes a troubled appearance in the evenings, and the monsoon in general sets in during the night. It is attended by such a thunder-storm as can hardly be imagined by those who have only seen that phenomenon in a temperate climate. It generally begins with violent blasts of wind, which are succeeded by floods of rain. For some hours, lightning is seen almost without intermission; sometimes it only illumines the sky, and shows the clouds near the horizon; at other times, it discovers the distant hills, and again leaves all in darkness; when, in an instant, it re-appears in vivid and successive flashes, and exhibits the nearest objects in the brightness of day. During all this time the distant thunder never ceases to roll, and is only silenced by some nearer peel, which bursts on the ear with such a sudden and tremendous crash as can scarcely fail to strike the most insensible heart with awe. (Malabar is most distinguished for the violence of the monsoon.) At length, the thunder ceases, and nothing is heard but the continued pouring of the rain, and the rushing of rising streams. The next day presents a gloomy spectacle; the rain still descends in torrents, and scarcely allows a view of the blackened fields: the rivers are swollen and discolored, and sweep down along with them the hedges, the huts, and the remains of the cultivation which was carried on during the dry season, in their beds.

"This lasts for some days, after which the sky clears, and discovers the face of nature changed, as if by enchantment. Before the storm, the fields were parched up, and, except in the beds of rivers, scarce a blade of vegetation was to be seen. The clearness of the sky was not interrupted by a single cloud, but the atmosphere was loaded with dust: a parching wind blew, like a blast from a furnace, and heated wood, iron, and every solid material, even in the shade: and immediately before the monsoon, this wind had been succeeded by still more sultry calms. But when the first violence of the monsoon is over, the whole earth is covered with a sudden but luxuriant verdure: the rivers are full and tranquil: the air pure and delicious; and the sky is varied and embellished with clouds. The effect of this change is visible on all the animal creation, and can only be imagined in Europe by supposing the depth of a dreary winter to start at once into all the freshness and brilliancy of spring. From that time the rain falls at intervals for about a month, when it comes on again with great violence, and in July the rains are at their height: during the third month they rather diminish, but are still heavy; and in September they gradually abate, and are often suspended till near the end of the month, when they depart amid thunders and tempests, as they came."

From the parallel of 30° to the pole in both hemispheres, the winds, as the influence of the sun is here less potent, occasionally obey other causes than those just enumerated. The general causes of winds in temperate climates operate with less force and constancy than in tropical countries; and the disturbing causes, such as the vicinity of land, change in atmospheric density from moisture and dryness, etc., act with more uncontrolled energy. Hence the winds of temperate climates are much less regular, and are called *variable*. Between the parallel of 30° and 50°, westerly winds prevail in both hemispheres; and these blow with so much uniformity, that they are almost as deserving of the name of *trade*-winds as the easterly winds within the tropics. They cross the Atlantic from Newfoundland to Cornwall, and traverse the Southern Ocean from the Plata to the Cape of Good Hope, and thence to New Holland. Hence the packets from New York to Liverpool make the voyage, on an average, in nearly half the time as those sailing in the opposite direction. According to a register kept by John Hamilton, the captain of a packet, during twenty-six voyages between Philadelphia and Liverpool, from 1799 to 1818, the prevailing winds, in 2029 days, was from the west. His tables present the following ratios:—

208	days from the northward,
167	" " " southward,
361	" " " eastward,
1101	" " " westward,
192	" " " variable,
2029	

These westerly winds beyond the tropics, it is generally supposed, are merely the upper equatorial currents of air descending to the earth's surface, which, transporting the celerity of equatorial rotation, on reaching the higher latitudes which have gradually less eastward motion, run faster than these parts, and consequently become westerly winds. In other words, these currents will appear to blow from the western quarter in proportion to the excess of their previous celerity above that of the parallels which they strike.

SUBSECTION 1.—*Land and Sea Breezes.*

The sea-breeze is felt more or less on the coasts of all warm countries; and it often occurs in places where the land-breeze is quite unknown. Commencing about 10 o'clock A. M., the sea-breeze continues throughout the day, till toward 6 P. M.; and at about 8 o'clock, when it has gradually died away, it is succeeded by a much lighter breeze from the land, which, continuing during the night, usually ceases at about 6 o'clock in the morning. The sea-breeze finds an explanation in the rarefaction of the incumbent atmosphere by the heat of the land, and the rushing in of the denser air of the sea to establish an equilibrium; and as the influence of the sun decreases, this breeze dies away. During the night, on the contrary, as the ocean parts with its caloric much more slowly than the land, the reverse action, to some extent, or the land-breeze, takes place; but this breeze is produced, in a great measure, by the descent of air from mountainous regions, flowing, by its gravity, toward the sea; and hence it is scarcely known at all on the flat coasts of America. Without the sea-breeze, many islands and coasts would be absolutely uninhabitable; and while this current is all purity and freshness, the land breeze is often laden with unhealthy exhalations from the forests and marshes.

SUBSECTION 2.—*Sirocco.*

The *Sirocco* is occasioned by the passage of a current of air over the heated sandy wastes of Arabia and Lybia, which render it so dry and rarefied as to unfit it for respiration. But in traversing the Mediterranean, it absorbs so large a quantity of moisture as to cause the dew-point, during its prevalence on the islands of that sea, to fall sometimes from ten to twenty degrees. "The walls of houses, stone floors, and pavements," says Dr. Hennen, "invariably become moist when the sirocco blows. I have seen the stone floors at Corfu absolutely wet without any rain having fallen." At the same time, a sudden and great rise of the thermometer occurs, accompanied by a haze which obscures the pure sky of those countries, the sun appearing dimmed and shorn of his beams. During this state of things, the inhabitants of Italy,

Malta, Sicily, or Corfu, are oppressed with excessive langour and a sinking of the mental energies.

The following remarks are from the pen of the philosophic John Davy, Esq., of the Medical Department of the British Army, who has had the most abundant opportunities of observation :—

"The south-east wind is well-known, and of evil report, under the name of Sirocco. Respecting this wind, much variety of opinion exists, and very contradictory accounts are to be found in authors. By some it is described as excessively damp; by some as extremely dry; it has even been described as both damp and dry, and one writer denies that it is possessed of any peculiar qualities. This discordancy has probably arisen from partial and superficial observation on the part of travellers, who may have drawn their inferences from exceptions in particular situations, and have generalized from them.

"The Sirocoo wind in Malta, and, it may be added, in the Mediterranean generally, as well as in the Ionian Islands, is invariably charged with moisture, and even more so in summer than in winter. When it blows with any strength, the difference between a moist thermometer and a dry one, exposed to it, seldom exceeds 4° or 5°. Its temperature is never very high, even in the height of the hot season. I have never seen it raise the thermometer above 86°. The atmosphere, when this wind prevails, is always hazy, as if palpable vapor were suspended in it. Dust is raised by it in a remarkable manner, and carried along with it.* The sensations which it produces at different seasons are far from being the same. In winter, when its temperature may be about 60°, it feels mild and agreeable. In spring and early summer, when its temperature may be about 70°, it is not generally unpleasant. It is chiefly in summer and autumn that it is disagreeably felt and complained of, when its temperature ranges between 75° and 85°. The higher its temperature, so much the more distressing are its effects, owing to the little evaporation which it produces. This is connected with its comparative humidity; and this, its humidity, is, I believe, the principal cause of all its peculiarities,—of the oppressive sensation of heat,—of the perspiration in which the skin is bathed,—of its relaxing and debilitating effects on the body, and its lowering and dispiriting effects on the mind. Other effects, too, which are unquestionable, may be referred to the same quality,—as its retarding the drying of paint,—the promoting the decomposition of animal and vegetable matter,—the rusting of metals,—the fermentation of wines, and the acetous fermentation,—to which may be added the propagation of odors."

Dr. Davy does not believe that these peculiar effects of the Sirocco are owing to any particular electric state, but are due solely to its humidity. From a series of experiments conducted by him "no well marked difference," he says, "was perceptible in the electrical condition of the atmosphere, from whatever quarter the wind blew, under ordinary circcumstances,—whether the clear north-east or north-west wind prevailed, or the hazy Sirocco, the electrical state of the atmosphere was found to be opposite to that of the earth,—the former negative, the latter positive."†

The *Solano* of Spain is only a modification of the Sirocco. "We have experienced it," says Dr. Traill, in the Encyclopædia Britannica, "as most oppressive on the eastern shores of Spain; and it is greatly detested by the natives, who gravely remark, that 'no animals except a pig and an Englishman are insensible to the Solano.' The Italian condemnation of a stupid work, 'era scritto in tempo del Sirocco,' is not more pointed than the Spanish adage, 'no rogar alguna gracia en tiempo de Solano,' not to ask any favor during the Solano; and both proverbs sufficiently indicate the belief of the people of southern Europe in the disagreeable qualities of the S. E. wind. We have observed fine dust deposited from the Solano or *Levanter* at Gibraltar, and to this we partly attribute the haze with which it is accompanied. If this dust be brought with the Solano from Africa, it is less surprising than the following instance of dust carried by the easterly wind into the Atlantic. On the morning of the 19th January 1826, when the Clyde East Indiaman was on her voyage to London, in lat. 10° 40′ N., and long. 27° 41′ W., her rigging was observed to be covered with an impalpable powder of a brownish color, and on unfurling the sails at two P. M. to catch the breeze, they emitted clouds of dust, which had lodged in them during a strong gale from the E. and N. E. In this case, the nearest land in that direction was about 700 miles distant."

The *Harmattan* of the west coast of Africa, the *Samiel* of the Turks, the *Simûn* of the Arabs, and the *Khamsin* of Syria, all seem to be mere modifications of aërial currents produced by the same causes which give rise to the Sirocco. There is this striking difference, however, that whilst the Sirocco acquires much moisture in crossing the Mediterranean, these other winds are characterised by extreme aridity, derived from blowing over sandy deserts intensely heated by the sun. Laden with impalpable sand which penetrates into the closest packages, these winds cause difficult respiration, a shrivelled skin, and a distressing sense of heat. Their effect is compared by Volney to the sensation produced by the hot air from a baker's oven.

SUBSECTION 3.—*Whirlwinds and Hurricanes.*

The name of *Whirlwind* has been given to eddying currents, produced by the contact of two or more atmospheric streams coming from different points of the compass, and also depending seemingly on electricity. It sometimes rages with surprising fury, overthrowing buildings and tearing up trees by the roots; and when it passes through a forest, it often leaves a long lane of inconsiderable breadth. But fortunately, this violent agitation of the atmosphere is usually local in its operations. It is in some parts of Africa that the effects of the whirlwind are most to be dreaded. During the storms that often rage in the desert, as described by Bruce, the loose sand is transported into the air in such dense clouds as to intercept the piercing rays of even an African sun, whilst at other times it is raised into massive and gigantic moving columns. Wo to the traveller that encounters this terrific phenomenon! How sublime, but at the same time how fearful the sight, to behold on every side enormous pillars of sand, moving with impetuous violence over the unmeasured waste, their tops reaching to the clouds, and their base sometimes unsupported save by the attenuated air!

The *Hurricanes* of the West Indies, the *Typhons* of the Chinese Seas, the *Ox-eye* of the Cape, and the *Tornadoes* of all tropical climates, have been well described by navigators and others. They consist of violent and extraordinary agitations of the air, generally accompanied by thunder-storms. Fortunately, they are usually of brief duration.

In reflecting upon these terrific phenomena, let not the reader be led to infer that any terrestrial agent is active for the mere purpose of destruction. Although the traveller may be occasionally overwhelmed in the desert by vast masses of sand, the stately ship may be swallowed up in the furious agitation of the mighty deep, or the smiling valley may be rendered desolate in an hour, yet the same agent still ministers to the wants and pleasures of man. The effects of winds combine utility and pleasure. By maintaining a perpetual agitation of the atmosphere, the miasmata exhaled from the earth are dissipated; whilst the clouds destined to fertilize the soil, are transported upon their wings. As nature adapts means to the accomplishment of her ends, so myriads of seeds furnished with their little pinions, ride upon the tempest and extend afar the empire of vegetation. Nor has man, in his ingenuity, neglected to avail himself of this agent; for, as the ocean is the highway of nations, the winds are the untiring coursers which impel our ships from shore to shore, thus carrying over its swelling bosom the riches and intellect of foreign climes.

SUBSECTION 4.—*Water-spouts.*

This curious and perplexing phenomena may here be brought under notice as having some connection with atmospheric currents. These meteors, although more frequently met with at sea, under the form of enormous clouds of a columnar shape, or that of an inverted cone, several hundred feet high, yet often make their appearance on land, destroying every thing, including trees and houses, that opposes their violent impetuosity. It is still a disputed point among meteorologists, whether the phenomenon is due to the agency of electricity, or to the mechanical action of whirlwinds. Dr. Buchanan, who saw water-spouts several times during a voyage to and from India, says that his attention was first attracted to the phenomenon by observing a dark heavy cloud which threw out a long curved spout, while at the same time a thick fog rose out of the sea. This fog was of the same color as the spout, and resembled the smoke of a steam-engine. After an interval of about two minutes, the spout rushed down and joined the cloud which had risen from the sea. The following diagram, according to Mr. Maxwell, represents the different appearances which these phenomena generally assume. They appear, he says, at their first formation,

WATER-SPOUTS.

of a conical tubular form, dropping from a black cloud before any disturbance of the sea is observable. The fog on the sea now appears and ascends, and the black conical clouds descends, until both join. After several minutes, the black cloud withdraws itself and the fog recedes into the sea; but sometimes a thin transparent tube connected with the latter still remains for a short time. The firing of several guns will generally destroy them, either by being struck by shot or by the agitation caused in the air by the discharge. In one instance, witnessed by the Honorable Captain Napier, as described by him in the Philosophical Journal, in which a shot passed through a water-spout at the distance of one-third from its base, it presented for a minute the appearance of being cut horizontally in two parts, the divisions waving to and fro as if agitated by winds, but suddenly the ends reunited, and soon after the whole was dissipated in an immense dark cloud and a shower of rain. Many observers assert that, when the column from the cloud reaches the sea, they have distinctly seen the sea-water move up its hollow centre; but if, as is stated by others, the water discharged on the bursting of a water-spout is always fresh, it follows that any water derived from the sea must have arisen in the form of vapor.

SUBSECTION 5.—*Observations upon Winds, and the degree of their velocity.*

It remains now to say a word in regard to the observations proper to be made in reference to winds. According to the "Instructions for the Scientific Expedition to the Antartic Regions, prepared by the President and Council of the Royal Society of London," the points most important to remark respecting the winds, are:

1. Its average intensity and general direction during the several portions of the day devoted to observation.
2. The hours of the day or night when it commences to blow from a calm, or subsides into one from a breeze.
3. The hours at which any remarkable changes of its direction take place.
4. The course which it takes in veering, and the quarter in which it ultimately settles.

5thly. The usual cause of *periodical winds*, or such as remarkably prevail during certain seasons, with the law of their diurnal progress, both as to direction and intensity; at what hours, and by what degrees they commence, attain their maximum, and subside; and through what points of the compass they run in so doing.

* Perhaps in consequence of the specific gravity of the dust being diminished by the absorption of moisture.

† Notes and Observations on the Ionian Islands and Malta.

6thly. The existence of crossing currents at different heights in the atmosphere, as indicated by the courses of the clouds in different strata.

7thly. The times of setting-in of remarkably hot or cold winds, the quarters from which they came, and their courses, as connected with the progressive changes in their temperature.

8thly. The connection of rainy, cloudy, and fair weather, with the quarter from which the wind blows, or has blown for some time previously.

Many ingenious instruments have been invented for indicating the variations of winds. The *anemoscope* shows the *direction* of winds, registering upon a slate the *maxima* and *minima*, thus saving the trouble of frequent daily observations. The *anemometer* determines the varying *force* of winds. There are several of these instruments, the acting principle of which is the direct pressure of the wind on a given surface, maintained by a vane perpendicular to the direction of the breeze. There are different modes of measuring this pressure, several of which are very ingenious. Some of these instruments give both the force and direction of winds.

The velocity of the wind varies from a barely perceptible motion up to 100 miles in an hour; and, according to some, the maximum is considerably higher. It is generally estimated that a gentle breeze moves four or five miles an hour, and has a force equal to two ounces on a foot square; that a brisk pleasant gale has a motion of ten or fifteen miles, with a force of twelve ounces; that a high wind moves at the rate of thirty or thirty-five miles, with a force of five or six pounds; and that a hurricane, levelling houses, trees, etc., has a velocity of 100 miles an hour, and a force of 49 pounds on the square foot.

Winds are considered as being produced in two ways—by *propulsion* and by *aspiration*. When the blast and current are in the same direction, as is most usually the case, wind is said to be caused by *propulsion*; and, on the other hand, by *aspiration*, when the current is in one direction and the blast in the opposite course. Of this latter kind, there are many instances, designated as storms and hurricanes, which are characterized chiefly by their excessive velocity. They seem to *begin* at that point *toward* which they blow—a result which has been ascribed to a vacuum in the atmospheric ocean, produced by a fall of rain caused by the sudden condensation of vapors. The N. E. storms on our coast afford us, unfortunately, too many illustrations of these hurricanes, which, commencing over the Gulf of Mexico, move toward the north by *aspiration*. As early as 1740, these phenomena attracted the notice of our distinguished countryman, Dr. Franklin. This extraordinary philosopher relates that he was prevented from observing an eclipse of the moon at Philadelphia, by a N. E. storm, which came on about 7 o'clock in the evening; and this storm, he was subsequently surprised to learn was not experienced in Boston until four hours later. This led him to compare many other accounts of this storm as it manifested itself at various localities; and the result was the discovery that, notwithstanding it blew from the N. E., it was all the while advancing from the S. W., at the rate of 99 miles per hour, o nearly 145 feet per second.

SUBSECTION 6.—*Redfield's Theory of Storms.*

It is but a comparatively short period since the belief was prevalent that a gale differed from a breeze only in the velocity of the air which was put in motion; and hence a hurricane was supposed to be quite satisfactorily explained, when it was decribed as a wind travelling in a rectilineal direction at the rate of 100 or 120 miles an hour. Franklin, as stated above, was aware that what are called north-east storms, came in reality from the south-west, that is, that they were first felt in Florida, then in Georgia, the Carolinas, Virginia, New Jersey, New York, Connecticut, Massachusetts, etc.; but his ingenious explanation that from some cause a partial vacuum was formed near the point where the gale was first experienced, causing currents of air toward the vacant space, which movements were continued from the south-west to the north-east, is not near so satisfactory as the theory of W. C. Redfield, Esq., of New York. The doctrine maintained by Mr. Redfield, and substantiated by Lieut. Col. Reid, of the Royal Engineers, is, that a hurricane or great gale is simply a whirlwind, the main body of the storm whirling in a horizontal circuit round a vertical or somewhat inclined axis of rotation, which is carried onward with the storm; and that the direction of this rotation, in the northern hemisphere, is from right to left, or in a course contrary to that of the hands of a watch, while the storms of the southern hemisphere revolve in the opposite direction. These views of Mr. Redfield are based on many observations of storms during a period of upward of twenty years. As the following "*Observations on the Hurricanes and Storms of the West Indies, and the Coast of the United States, by W. C. Redfield*," extracted from "Blunt's American Coast Pilot," present a condensed view of the subject, their introduction here demands no apology:—

"It has been found, by a careful attention to the progress and phenomena of the more violent storms which have visited the Western Atlantic, that they exhibit certain characteristics of great uniformity. This appears, not only in the determinate course which these storms are found to pursue, but in the direction of wind, and succession of changes which they exhibit while they continue in action. The same general characteristics appear also to pertain, in some degree, to many of the more common variations and vicissitudes of winds and weather, at least in the temperate latitudes. The following points may be considered as established.

"1. The storms of greatest severity often originate in the tropical latitudes, and, not unfrequently, to the northward or eastward of the West India Islands; in which region they are distinguished by the name of *hurricanes*.

"2. These storms cover at the same moment of time, an extent of contiguous surface, the diameter of which may vary in different storms, from one hundred to five hundred miles, and in some cases they have been much more extensive. They act with diminished violence toward the exterior, and with increased energy toward the interior, of the space which they occupy.

"3. While in the tropical latitudes, or south of the parallel of 30°, these storms pursue their course or are *drifted* toward the west, on a track which inclines gradually to the northward, till it approaches the latitude of 30°. In the vicinity of this parallel, their course is changed somewhat abruptly to the northward and eastward, and the track continues to incline gradually to the east, toward which point, after leaving the lower latitudes, they are found to progress with an accelerated velocity.

"The rate at which these storms are found thus to advance in their course, varies much in different cases, but may be estimated at from twelve to thirty miles an hour. The extent to which their course is finally pursued, remains unknown; but it is probable, that as they proceed, they become gradually extended in their dimensions, and weakened in their action, till they cease to command any peculiar notice. One of the hurricanes of August 1830, has been traced in its daily progress, from near the Caribbee Islands, to the coast of Florida and the Carolinas, and from thence to the banks of Newfoundland; *a distance of more than three thousand miles*, which was passed over by the storm in about six days. The duration of the most violent portion of this gale, at the different points over which it passed, was about twelve hours, but its entire duration was in many places, more than twice that period. Another hurricane which occurred in the same month, passed from near the Windward islands, on a more eastern but similar route, and has also been traced in its daily stages by means of the journals and reports of voyagers, *near two thousand five hundred miles*. It was in this storm that the Russian Corvette Kensington, Captain Ramsay, suffered so severely. The hurricane of August 1831, which desolated the island of Barbadoes, on the 10th of that month, the daily progress of which has also been ascertained, passed in nearly a direct course to the northern shores of the Gulf of Mexico and New Orleans, where it arrived on the 16th of the same month, having passed over a distance of *twenty-three hundred statute miles* in six days after leaving Barbadoes. Many cases of like character might be adduced.

"4. The *duration* of the storm at any place within its track, depends upon its extent and the rate of velocity at which it moves, as these circumstances are found to determine the time which is required for the storm to pass over any given locality falling within its route. Storms of smaller extent, or dimensions, are usually found to move from one place to another with greater rapidity than larger storms.

"5. The direction and strength of the wind exhibited by a storm over the greater portion of its track, is found *not to be in the direction of its progress*. The rate or velocity of this progress would indeed be insufficient to produce any violent effect.

"6. In the lower latitudes while drifting to the westward, the direction of the wind at the commencement, or under the most advanced portion of these storms, is from a *northern* quarter, usually at some point from north-east to north west; and during the latter part of the gale, it blows from a *southern* quarter of the horizon, at all places where the whole gale is experienced.

"7. After reaching the more northern latitudes, and while pursuing their course to the northward and eastward, these storms commence with the wind from an eastern or southern quarter, and terminate with the wind from a western quarter, as will appear more distinctly under the three following heads;—the latter portion of the storm being usually attended with broken or clear weather.

"8. On the outer portion of the track, north of the parallel of 30°, or within that portion of it which lies *farthest* from the American coast, these storms exhibit at their commencement, a *southerly* wind, which, as the storm comes over, *veers gradually to the westward*, in which quarter it is found to terminate.

"9. In the same latitudes, but along the *central portions of the track*, the first force of the wind is from a point near to *south-east*, but after blowing for a certain period, it *changes suddenly*, and usually after a short intermission, to a point nearly or directly opposite to that from which it has previously been blowing, from which opposite quarter it blows with equal violence till the storm has passed over or has abated. This sudden change of a south-easterly wind to an opposite direction, *does not occur toward either margin of the storm's track*, but only on its more central portion, and takes effect in regular progression along this central part of the route, from the *south-west* toward the *north-east*, in an order of time, which is exactly coincident with the progress of the storm, in the same direction. It is under this portion of the storm, that we notice the greatest fall of the barometer, and the mercury usually begins to rise a short time previous to the change of wind. In this part of the track, the the storm is known as a *south-easter*, and is usually attended with rain previous to the change of wind, and perhaps for a short time after.

"10. On that portion of the track which is *nearest* the American coast, or which is the farthest inland if the storm reaches the continent, the wind commences from a more eastern or north-eastern point of the horizon, and afterwards veers more or less gradually, by north, to a north-western or westerly quarter, where it finally terminates. Here also the first part of the storm is usually, but not always attended with rain, and its latter or western portion with fair weather. The first or foul weather portion of the storm, is on this part of its track, recognized as a *north-easter*.

"It should be noted, however, that near the latitude of 30° and on the shores of Carolina, where the storm enters obliquely upon the coast, while its track is rapidly changing from a northwardly to an eastwardly direction, the wind on the central track of the storm will commence from an eastern or north-eastern point of the compass, and will gradually become south-easterly as the storm approaches its height.

"11. A full and just consideration of the facts which have been stated, will show conclusively that the portion of the atmosphere which composes for the time being the great body of the storm, whirls or blows in a horizontal circuit, around a vertical or somewhat inclined axis of rotation which is carried onward with the storm; that the course or direction of this circuit of rotation is from *right to left*; and that the storm operates in the same manner, and exhibits the same general characteristics, as a tornado or whirlwind of smaller dimensions; the chief difference being in the magnitude of the scale of operation.* This view of the subject, when fully comprehended, affords a satisfactory solution of the otherwise inexplicable phenomena of storms; and will also be found to accord entirely with the fact, which has been previously stated, that in the phases or changes which pertain to a storm, the wind, on one margin of its track, veers in seamen's phrase *with the sun*, or from *left to right*, while under the opposite margin of the same storm it veers *against the sun*, or from *right to left*: for this peculiarity

* It is to be understood that the diameter of the whirlwind which constitutes the storm is commensurate with the width of the track over which the storm passes.

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necessarily attends the progress of any whirlwind which operates horizontally.

"12. The Barometer, whether in the higher or lower latitudes, always sinks while under the first portion or moiety of the storm on every part of its track, excepting, perhaps, its extreme northern margin, and thus often affords us the earliest and surest indication of the approaching tempest. The mercury in the Barometer always rises again during the passage of the last portion of the gale, and commonly attains the maximum of its elevations on the entire departure of the storm.

"The great value of the Barometer to navigators is becoming well understood, and its practical utility might be greatly increased by hourly entries of the precise height of the mercurial column, in a table prepared for the purpose. Its movements, unless carefully recorded, often escape notice or recollection; which may easily happen at those times when a distinct knowledge of its latest variations might prove to be of the greatest importance.

"In the foregoing statements our design has been to designate in a summary manner the principal movements which, in these regions at least, constitute a storm: and we do not attempt to notice the various irregularities, and subordinate or incidental movements and phenomena of the atmosphere, with which a storm may chance to be connected, or which may necessarily result from such violent movements in a fluid which is so tenuous and elastic in its character. It may be remarked in general, that the most active or violent storms are usually the most regular and uniform in the developement of those characteristic movements which we have already described. It is also probable, that the vortex or rotative axis, of a violent gale or hurricane, oscillates in its course with considerable rapidity, in a moving circuit of moderate extent, near the centre of the hurricane; and such an eccentric movement of the vortex may, for ought we know, be essential to the continued activity or force of the hurricane. Such a movement will fully account for the violent *flaws* or *gusts* of wind, and the intervening *lulls* or remissions which are so often experienced towards the heart of a storm or hurricane, when in open sea; but of its existence we have no positive evidence.

"It frequently happens that a storm, during the first part of its progress over a given point, fails to take effect upon the surface, while it exhibits its full activity at a greater altitude. This commonly happens when this portion of the storm arrives from, or has recently blown over a more elevated country, or is passing or blowing from the land to the sea. On land, the most violent effects are usually felt from those storms which enter and blow from the open ocean upon the shores of an island or continent. Upon the latter, under such circumstances, the *first* part of the gale is usually the most severe, and that coast of an island upon which a storm first enters, or blows, also suffers most from the early part of the gale, but its later or receding part, often acts with the greatest fury upon the opposite side of the island, which had previously derived some degree of shelter from the intermediate elevations and other obstacles opposed to the force of the wind, the benefit of which is now lost by its counter direction from the open ocean. Owing to similar causes, the force of the storm is sometimes very unequal at different places, situated in nearly the same part of its track, and such inequality, as we have before intimated, necessarily pertains to two places, one of which is near the centre and the other towards the margin of the route.

"Of the multitude of facts by which these views might be illustrated, we will only state, that in the late hurricane of Barbadoes, (that of August 1831) the trees near the northern coast of that island, lay from N. N. W. to S. S. E. having been prostrated by northerly wind in the earlier part of the storm, while in the interior and some other parts of the island, they were found to lay from south to north, having fallen in the later period of the gale.—That after the same hurricane, advices which were received from the island of St. Croix and Porto Rico, (which lay near the northern margin of its track) stated that no hurricane had been experienced at these islands; but it afterwards appeared that some portions of these islands had suffered damage from this hurricane in the night of the 12th to 13th of August, two days after it had passed over the island of Barbadoes.—That the sea-islands which border the coast of Georgia and the Carolinas, are known to suffer greatly from these tempests, while little or no injury is sustained in the interior at the distance of a few miles from the coast. One of the most striking characteristics of these storms, is the *heavy swell* which in open sea is often known to extend itself on both sides of the track, entirely beyond the range of the gale by which it was produced. The last hurricane to which we have alluded, threw its swell with tremendous force upon the northern shores of Jamaica, having passed to the northward of that island.

"A variety of deductions may be drawn from the general facts which we have stated, some of which, though deeply interesting to the philosopher and votary of science, might be out of place in a nautical work of this description. For ourselves, we disclaim any bondage to existing theories in meteorology; and shall on the present occasion, only proceed to notice a few of the more practical inferences which, to navigators and others may, perhaps, be of no doubtful utility

"1. A vessel bound to the eastward between the latitudes of 32° and 45° in the western part of the Atlantic, on being overtaken by a gale which commences blowing from any point to the eastward of S. E. or E. S. E. may avoid some portion of its violence, by putting her head to the northward, and when the gale has veered sufficiently in the same direction, may safely resume her course. But by standing to the southward under like circumstances, she will probably fall into the heart of the storm.

"2. In the same region, vessels, on taking a gale from S. E. or points near thereto, will probably soon find themselves in the heart of the storm, and after its first fury is spent, may expect its recurrence from the opposite quarter. The most promising mode of mitigating its violence, and at the same time shortening its duration, is to stand to the southward upon the wind, as long as may be necessary or possible; and if the movement succeeds, the wind will gradually head you off in the same direction. If it becomes necessary to heave too, put your head to the southward, and, if the wind does not veer, be prepared for a blast from the north-west.

"3. In the same latitudes, a vessel scudding in a gale with the wind at the east or north-east, shortens its duration. On the contrary, a vessel scudding before a south-westerly or westerly gale, will thereby increase its duration.

"4. A vessel which is pursuing her course to the westward or southwestward, in this part of the Atlantic, meets the storms in their course, and thereby shortens the periods of their occurrence; and will encounter more gales in an equal number of days, than if stationary, or sailing in a different direction.

"5. On the other hand, vessels while sailing to the eastward or northeastward, or in the course of the storms, will lengthen the periods between their occurrence, and consequently experience them less frequently than vessels sailing on a different course. The difference of exposure which results from these opposite courses, on the American coast, may in most cases be estimated as nearly two to one.

6. The hazard from casulties, and of consequence the value of insurance, is enhanced or diminished by the direction of the passage, as shown under the two last heads.

"7. As the ordinary routine of the winds and weather in these latitudes, often corresponds to the phases which are exhibited by the storms as before described, a correct opinion, founded upon this resemblance, can often be formed of the approaching changes of the wind and weather, which may be highly useful to the observing navigator.

"8. A due consideration of the facts which have been stated, particularly those under our twelfth head, will inspire additional confidence in the indications of the *barometer*, and these ought not to be neglected, even should the fall of the mercury be unattended by any appearances of violence in the weather, as the other side of the gale will be pretty sure to take effect, and often in a manner so sudden and so violent as to more than compensate for its previous forbearance. Not the least reliance, however, should be placed upon the prognostics, which are usually attached to the scale of the barometer, such as *Set-Fair*, *Fair*, *Change*, *Rain*, &c. as in this region at least, they serve no other purpose than to bring this valuable instrument into discredit. It is the mere rising and falling of the mercury, which chiefly deserves attention, and not its conformity to a particular point in the scale of elevation.

"9. These practical inferences apply in terms, chiefly to storms which have passed to the northward of the 30th degree of latitude on the American coast, but with the necessary modification as to the point of the compass, which results from the westerly course pursued by the storm while in the lower latitudes, are for the most part equally applicable to the storms and hurricanes which occur in the West Indies, and south of the parallel of 30°. As the marked occurrence of tempestuous weather is here less frequent, it may be sufficient to notice that the point of direction, in cases which are otherwise analagous, is in the West Indian seas, about ten or twelve points of the compass *more to the left* than on the coast of the United States in the latitude of New York.

"Vicissitudes of winds and weather on this coast which do not conform to the foregoing specifications, are more frequent in April, May, and June, than in other months. Easterly or southerly winds under which the barometer rises, or maintains its elevation, are not of a gyratory or stormy character; but such winds frequently terminate in the falling of the barometer and the usual phenomena of an easterly storm.

"The typhoons and storms of the China sea and eastern coast of Asia, appear to be similar in character to the hurricanes of the West Indies and the storms of this coast, when prevailing in the same latitudes. There is reason to believe that the great circuits of wind, of which the trade winds form an integral part, are nearly uniform in all the great oceanic basins; and that the *course* of these circuits and of the stormy gyrations which they may contain, is, in the southern hemisphere, in a *counter-direction* to those north of the equator, producing a corresponding difference in the general phases of storms and winds in the two hemispheres."

Subsection 7.—*Espy's Theory of Storms.*

The theory of Hutton relative to the deposition of water in the form of rain, ever since its promulgation about the year 1787, has maintained, in the absence of any other plausible rival theory, almost undisputed sway throughout the scientific world. As this theory has been already illustrated and several obvious objections have been adduced, any further elucidation is not deemed necessary. A new theory of storms by Mr. Espy of Philadelphia, which professes, in his own words, at once to explain "all the seven phenomena of rain, hail, snow, waterspouts, winds, and barometric fluctuations," has been, within a few years, presented to the scientific public; and as this theory commands a good deal of attention and respect, a brief synopsis of its leading features is surely demanded in this work. As the substance of the theory appears to be embraced in an article by L. H Parsons, A. M., in the "American Almanac" for 1843, a portion of it will be here adopted:

"1. Atmospheric air is subject to *expansion*,—either by heat, or by a diminution of pressure.

"2. Aqueous vapor is specifically lighter than atmospheric air,—its weight, under given circumstances, being but about five-eighths of that of air.

"3. When a portion of air becomes lighter than the surrounding air, from expansion by heat, from being more lightly charged with vapor, or from any other cause, it ascends.

"4. Air, in ascending from a lower to a higher region, is subject to diminished pressure, and consequently to expansion.

"5. The atmosphere is capable of containing, and does always contain, a certain quantity of water, in a state of transparent vapor.

"6. This capacity of the atmosphere for containing water increases much more rapidly than the temperature.*

"7. The quantity of water, actually in solution, varies greatly, at different times and places, independently of the temperature; the air, at a given temperature, sometimes being filled nearly or quite to the extent of its capacity, while at others, it falls far short of it.

"8. If from any cause, the temperature of a portion of air, containing a given quantity of vapor, be reduced to a certain point, that is, at all below the dew-point,† it must deposite a portion of the water.

* At 32° Fah. the air is capable of holding 1.240th only of its own weight of vapor: at 52°, it is capable of holding twice as much, or 1.120th of its own weight; at 72°, 1.62d, and at 92°, 1.32d of its own weight.

† The dew-point is the degree of temperature, at which moisture begins to be precipitated. It may be ascertained by placing cold water (in summer) or a refrigerating mixture (in winter) in a tumbler, and observing the

"9. Expansion, arising from diminished pressure, is attended by diminished temperature. The actual diminution of temperature, on this account, in ascending from the surface of the earth, is about one degree and a fourth, for every hundred yards; and consequently air, highly charged with vapor, that is, with a high dew-point, would not have to ascend very high before condensation must commence.*

"10. The condensation of vapor is attended with the disengagement of a very large quantity—more than a thousand degrees—of latent caloric, in other words sufficient caloric is set at liberty, by the condensation of a given quantity of vapor, to raise the temperature of a hundred times that quantity of matter (of the same specific caloric) ten degrees.†

"Now the theory is this. Air, near the surface of the earth, becoming heated to an unusual degree, or becoming highly charged with aqueous vapor, must rise. The tendency, it is supposed, would be to rise in a column or columns; the air surrounding each column, running in to supply the vacuum, and, if similarly heated or charged with vapor, following the other upward. If many up-moving columns should be formed in the same neighborhood, those not very remote from each other, as they increased in size, would probably run into each other, and form one great column. Ascending from the surface of the earth, this up-moving mass is subject to less and less pressure from the superincumbent atmosphere. As this pressure is removed, the air, of course, expands, and consequently grows colder. If the ascending air is very dry, that is, if it has a low dew-point, or if other circumstances, which will soon be mentioned, are unfavorable, its temperature, and that of the air through which it passes, will probably come to an equilibrium, and the force of the upward motion be spent, without any cloud being formed, or at most, without a cloud that will produce rain. But if the air be highly charged with vapor, it will not have to ascend very far before the temperature will be reduced by expansion, to such a degree as to cause a portion of the vapor to condense into cloud. The instant this takes place, the latent caloric, or caloric of elasticity, of the condensed vapor is evolved, and acts upon the air in which the cloud is formed, and, as it continues to ascend, heats it up, or rather prevents it from cooling down, as it did previously, and as it would otherwise do, from expansion. Mr. Espy has shown that it must cool only about half as fast after, as before condensation commences; that is, about five-eights of a degree to a hundred yards.‡ The tendency of this new, and continued (as it will be) accession of heat, will obviously be, to disturb still further the equilibrium between the ascending column and the surrounding air; and, of course, to increase its tendency and velocity upward. At the same time, the greater the velocity of the upward current, the more rapid will be the condensation, not only from the greater quantity of vapor brought by the rapid current under the influence of the causes which produce condensation, but by the greater degree of cold arising from the extraordinary expansion, caused by the upward rush of the air; thus causing an extension of the cloud-forming process downward, as well as upward.

"To produce rain, it is necessary, not merely that there should be a high dew-point, an upward current, and the formation of cloud; the ascending column, or vortex, must extend upward and unbroken to a very considerable height beyond the point where cloud first commences forming. And that can hardly take place, unless the mass of the atmosphere through which it ascends, is comparatively at rest; or unless the upper and lower currents coincide to some extent, in direction and force. If the column of cloud, in ascending, enters a current moving in an opposite direction to that below, or moving in the same direction, but with a much greater, or much less velocity, its top will be liable to be broken off, and swept away; thus destroying, or greatly weakening, the force of the vortex, and preventing the formation of cloud of sufficient altitude;—in other words, preventing the condensation of vapor in sufficient quantity to produce rain.

"To supply and maintain this upward current, the theory supposes the surrounding air, at and near the surface of the earth, to flow inward,—that is, that the *wind* in the borders of a storm, and probably beyond its borders, blows inward, from all directions, toward the centre,—ascending, of course, more or less, as it approaches the central vortex. As the column of air and cloud rises *above* the main body of the atmosphere, it must, of course, spread, and flow outwards, in the form of an annulus; chiefly, however, in the direction of the upper current. And as this upper current probably controls the general direction and velocity of the storm itself, it would form a great wave, above the proper level of the atmosphere, moving along with, or rather in advance of, the storm. The first effect of this aërial wave would be an increased pressure at the surface of the earth. This increased pressure would cause a flow, or a tendency to flow, in all directions *from* the point where it is greatest:—toward the storm in that direction, and *from* it in the opposite direction. So that, while within certain limits, surrounding the storm, the wind would blow inward, toward the centre, it would seem, that beyond those limits, at least, in one direction, and possibly in others, the wind would, or might, blow *from* the storm.

"As to the *course* of storms, in passing over the earth's surface, Mr. Espy supposes, as above intimated, that they are governed by an upper current of the atmosphere,—by the uppermost current which the vortex penetrates. He supposes that the whole ascending column obeys the impulse given to its head, as a rope suspended from a balloon, even though the end dragged upon the ground, would, in its whole length, follow the motion of the balloon. It is quite probable, if not certain, that the direction of most large storms, does coincide with, if it is not controlled by, an upper current."*

Mr. Espy, as previously remarked, maintains that this theory, which, in the above extracts, is applied only to rain-storms, also explains satisfactorily several other atmospheric phenomena, which will now be severally briefly noticed.

As regards the formation of SNOW, the only variation from the atmospheric conditions producing rain, according to Mr. Espy, is a temperature so low, as to freeze the particles of water, after they have been condensed, but before they have coalesced into drops.

In the production of HAIL, this theory supposes a very high dew-point, not only absolutely but relatively to the temperature. Hence, when an ascending column is formed, as the quantity of vapor in solution is large, the condensation commences low; and consequently the development of caloric, in proportion to the ascent, is rapid and great, thus causing a great disturbance of equilibrium. This upward current, Mr. Espy supposes to be so violent as to carry up with it the drops of water into the region of perpetual frost; and that here, becoming congealed, they are thrown out by the spreading top of the column, and permitted to fall to the ground. That hail should not always be produced, when the velocity of the upward current is sufficient to produce the effect just described, may be owing, according to Mr. E., to a whirlwind motion within the vortex, thus throwing the drops outward before reaching the region of frost; or even supposing hail-stones of moderate size to be formed, and thrown outside of the column, they may be dissolved, in falling through an atmosphere of high temperature, before reaching the ground.

TORNADOES AND WATER SPOUTS are referrible, by this theory, precisely to the same atmospheric conditions as those which are productive of hail, only that their operation is required to be more intense, that is, the dew-point must be so high as to approach very nearly the temperature of the atmosphere, which last must be in a state peculiarly favorable to an upward current of great height. In both these meteors, the cloud, as generally described, descends; but, more properly speaking, it *forms* close to the surface of the earth or the water.

By this theory, too, were it really founded in nature, the *fluctuations of the Barometer* might be naturally and easily explained. In proportion to the violence of the upward current at the centre of storms, must there be a diminution of atmospheric pressure, and a consequent depression of the barometric column; whilst at the outside of the storm, under the annulus, there must, at the same time, exist an increased atmospheric pressure, and a consequent rise of the barometer. But unfortunately for the beauty and simplicity of this theory, the barometric changes which have been frequently observed in storms are not easily reconciled with its principles; for there are storms, in the midst of which the barometer has been observed to be at the highest point. Many other objections might, indeed, be urged against Mr. Espy's theory, were it compatible with the design of this work. Let it suffice to refer to Mr. Espy's great fundamental position, that there is an inward tendency of the air in the borders of a storm towards its centre,—a conclusion which he has attempted to establish by a great number of observations collected from different parts of this and other countries. The proof of this central tendency of the wind, however, is insufficient and unsatisfactory; and, on the other hand, we have almost conclusive evidence in favor of a *whirling* motion, in the investigations of storms by Mr. Redfield, Colonel Reid and Prof. Dove. The diagram at the top of the next page, from the Journal of the Franklin Institute, containing "Remarks on Mr. Espy's Theory of Centripetal Storms, &c. By W. C. Redfield," will illustrate the peculiar views of each. In fig 1, the centripetal theory of Mr. Espy, as applied to the storm of 1821, is shown, which, in the latitude of Philadelphia, was moving nearly N.N.E., as indicated by the line and arrow head *c, c*; and fig. 2 illustrates the rotary or whirlwind theory of Mr. Redfield as applied to the same storm, which, in its advance would be intersected by the several geographical stations, *v, n, c, e, o*, on the several lines of arrow heads which are found in line with these stations on both figures. The direction of the several arrow-heads represents the direction, as well as the order of changes, which the wind would present to an observer, at each of these stations, according to the two theories."

That in tornadoes and water-spouts, there exists an *upward current* of great violence, we have direct and positive evidence. In the latter, as is well known, immense quantities of water are often carried up with great violence from the surface of the ocean; and in severe tornadoes, heavy bodies are not unfrequently raised perhaps perpendicularly, hundreds of feet from the surface of the earth. There is no positive evidence, however, of this upward current in ordinary storms, unless we admit as proof sufficient the fact of an inward motion at the surface of the earth, and simultaneously with it, a diminished barometric pressure at the centre of the storm. It is not, in truth, easy to imagine how this supposed centripetal movement of the winds, *even for hundreds of miles*, in nearly right lines from all sides towards the centre of the storm, is brought about, even supposing the barometer to be

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highest temperature at which dew settles upon it. Or it may be ascertained, approximately, by swinging rapidly, a thermometer, whose bulb is covered by a piece of wet cloth, and observing the lowest degree to which the mercury descends. The difference between the dew-point, and the temperature of the atmosphere, is called the *complement* of the dew-point.

* The dew-point is supposed to sink about one-fourth of a degree for every hundred yards of ascent, so that cloud will begin to form, at about as many hundred yards from the earth, as there are degrees between the dew-point, and the temperature of the air at the time.

† The *specific caloric* of a body, is the caloric which that body requires, as compared with water, to heat it any given number of degrees. The specific caloric of air is but a little more than one-fourth that of water. Consequently, assuming the caloric of elasticity to be a thousand degrees, which is below the truth, the caloric evolved by the condensation of a pound of vapor would be sufficient to raise the temperature of a hundred pounds of air nearly forty degrees: or of a thousand pounds, nearly four degrees. A thousand pounds of air, with a dew-point of 60°, would contain about eleven pounds of water, in a state of vapor. And a condensation of one pound of this water would require a depression of temperature of about three degrees only, which would take place from expansion, in ascending less than 600 yards. The caloric evolved by the condensation of one pound of water, could cause the thousand pounds of air, at that elevation, to occupy more than 100 cubic feet more space (after allowing for the diminution of bulk from the condensation of vapor) than it would otherwise have occupied. In other words, it would be about 1-120th the *lighter* than the surrounding air, which would of course give it a new impulse upward.

‡ This is strictly true, only when the dew-point is at about 70°. Above that, the depression would be less, and below, it would be a little more than five-eights of a degree to every hundred yards.

* The path of storms, originating in the torrid zone, is known to be a curve. Near the equator, their course is a little north of west,—gradually declining towards the north as the latitude increases, until in 25° or 30° of north latitude, their course is nearly north. Further north, the general course of storms is northeasterly. And in middle latitudes, say from 40° to 50° north, there is reason to believe the prevailing course to be not far from east: perhaps varying from one or two points north, to as many south of east.

exceedingly low at the centre of the storm. "It should be here kept in mind," says Redfield, "that half of the entire atmosphere lies below the height of three and a half miles. I have also good reasons for believing that the entire masses of our storms lie beneath this comparatively small elevation. What space for the exhibition of a vast centripetal column, whose semi-diameter is even imagined to have extended, in one case, from Iceland to Italy!" It is now an admitted fact that the barometer, in advance of nearly all great storms, rises considerably above its mean altitude, and that, during their passage, it sinks below this average,—fluctuations which bear a ratio to the violence of the storm.

In support of his theory, Mr. Espy adduces the fact that large fires, the eruption of volcanoes, etc., are attended by storms, apparently in the relation of cause and effect. These causes, when the dew-point and other circumstances are favorable, inasmuch as they have a strong tendency to produce an upward current in the atmosphere, are apt to be followed by storms.

The two theories of storms here noticed are of great practical importance to navigation, as already remarked, and scarcely less so to agriculture. Should the various relations above indicated be once indisputably established, the discovery will form an epoch in the annals of science; and to him fortunate enough to enrich science by unravelling these mysteries, a proud immortality is destined. As Mr. Espy is now connected, as meteorologist, with the medical department of the army, his untiring industry will afford him abundant opportunities of establishing the truth, if really founded in nature, of his simple and beautiful theory.

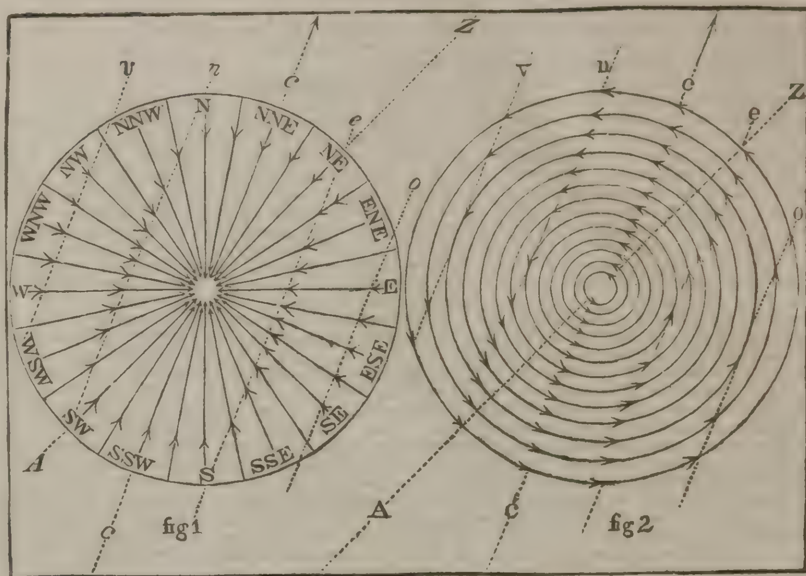


DIAGRAM ILLUSTRATIVE OF ESPY'S AND REDFIELD'S THEORIES OF STORMS.

SECTION VI.—Luminous Meteors.

If some of the phenomena last described, such as the trade-winds, do not strictly belong to the class of *accidental* meteorological phenomena, the same objection, if we except twilight, will surely not apply to what remains.

Subsection 1.—*Twilight.*

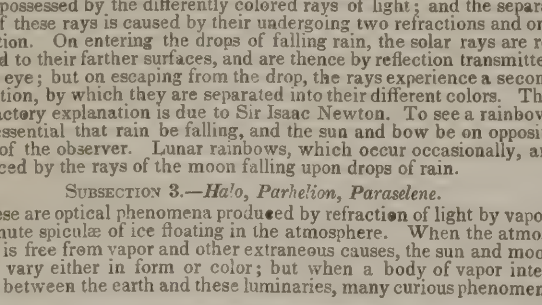
Many of the phenomena observed above and around us are the results of the refraction and reflection of light. Rays of light passing obliquely into a medium of different density are no longer straight, as when they move in a medium of uniform density and composition, but become bent or *refracted* towards the denser medium. Consequently, the rays of light from heavenly bodies, in traversing our atmosphere, as they are successively penetrating denser strata, are bent towards the earth; but the different rays suffer, according to their color, different degrees of refraction, that of red being the least, then orange, yellow, green, light blue, indigo, and violet. As regards the property of reflecting light, all solid bodies seem to possess it in a greater or less degree, the rays which are the most refrangible being also the most easily reflected. We may thus explain the phenomenon of morning and evening *twilight*. When the direct solar beams, in consequence of the descent of the sun beneath the horizon, can no longer, even by the aid of refraction, reach the earth's surface, they will strike upon the atmosphere, or the clouds which float in it, and produce, by being reflected downward, that secondary illumination, styled twilight.

Subsection 2.—*Rainbow.*

The *Rainbow* owes its formation to the different degrees of refrangibility possessed by the differently colored rays of light; and the separation of these rays is caused by their undergoing two refractions and one reflection. On entering the drops of falling rain, the solar rays are refracted to their farther surfaces, and are thence by reflection transmitted to the eye; but on escaping from the drop, the rays experience a second refraction, by which they are separated into their different colors. This satisfactory explanation is due to Sir Isaac Newton. To see a rainbow, it is essential that rain be falling, and the sun and bow be on opposite sides of the observer. Lunar rainbows, which occur occasionally, are produced by the rays of the moon falling upon drops of rain.

Subsection 3.—*Halo, Parhelion, Paraselene.*

These are optical phenomena produced by refraction of light by vapor, or minute spiculæ of ice floating in the atmosphere. When the atmosphere is free from vapor and other extraneous causes, the sun and moon never vary either in form or color; but when a body of vapor intervenes between the earth and these luminaries, many curious phenomena



PARHELIA OR MOCK SUNS.

are produced. The most singular effect, however, is induced when the upper regions of the atmosphere contain small, transparent, prismatic needles of ice, which, by varied refractions and reflections, may produce the most complicated phenomena. These several effects are known under the general term of Halo, while those resulting from solar influence have been distinguished by the name of Parhelia, and those from lunar, Paraselenæ. The halos around the sun and moon, sometimes called *coronæ*, consist of a broad circle of variable diameter, occasionally white, but more usually presenting a faint representation of the colors of the rainbow. Parhelia or *mock-suns* appear sometimes above and sometimes below the disc of the true sun. When in the polar regions, Captain Parry observed two parhelia, one of which, as it was thrown upon a thick cloud, was very bright and prismatic, while the other, having a blue sky at its back ground, was scarcely perceptible. Each of the mock-suns, as shown in the diagram, had attached to it bright yellow bands of light. Parhelia, it is supposed, are seated in the points of intersection of different halos, and derive their brightness from the union of several reflections. It would seem that in the polar regions, parhelia are not very uncommon, and that the cause is sufficiently permanent to keep up the appearance for several hours. Mock-moons or paraselenæ, which occur less frequently than parhelia, are generally ascribed to similar causes.

Subsection 4.—*Mirage.*

The cause of this phenomenon is the different refractive powers of the atmosphere, arising from its variable temperature. The curious effects of this unequal refraction are observed in all climates exposed to an extreme temperature. In arctic climes, the chilled traveller beholds before him mighty cities, with their battlements and towers; but, alas! he finds no shelter in the optical delusions produced by the pinnacles of icebergs and the snow-capt peaks of barren rocks. So, too, in the deserts of Africa, the drooping spirits of the traveller are often cheered by the apparition of cool streams and verdant foliage, which prove an airy vision less substantial than the morning cloud. This deception was experienced most painfully by the French army in Egypt. They beheld before them extensive lakes, covered with green islands with beautiful villages; but in vain did the exhausted soldiery press forward to reach this elysium, which seemed incessantly to fly before them like the fabled punishment of Tantalus. The effect produced upon the soldiers by this illusion is thus described by Baron Larrey, the Surgeon-in-Chief:—"Des plaines aqueuses semblaient nous offrir le terme de nos maux, mais ce n'était que pour nous replonger dans une plus grande tristesse, d'où résultaient l'abattement et la prostration de nos forces, qui se sont portés chez nos braves au dernier degré: appelé trop tard pour quelques-uns d'entre eux, mes secours devenaient inutiles et ils périssaient comme par extinction: cette mort me parut douce et calme; car l'un d'eux, me disait au dernier moment de sa vie, se trouver dans un bien être inexprimable: cependant j'en ai ranimé un très grand nombre avec un peu d'eau douce aiguisée de quelques gouttes d'esprit-de-vin, que je portais constamment avec moi dans une petite outre de cuir."

This phenomenon is sometimes witnessed in more temperate climes; as, for instance, at Ramsgate, in 1798, by that eminent philosopher, Dr. Vince. He beheld in the sky, immediately above a ship approaching the shore, the topmast only of which was visible above the horizon, two complete images of the whole vessel, one erect and one inverted. Both images remained visible after the ship had risen above the horizon; but, as it came into view, they gradually became indistinct. Many other instances of ships in the air are upon record. Captain Scoresby, in a voyage in the polar region, observed an inverted ship in the air. Having directed his telescope towards it, he found that it was his father ship, the Fame, notwithstanding it was at that time far below the horizon. "It was," says Captain S. "so well defined, that I could distinguish, by a telescope, every sail, the general rig of the ship, and its particular character; insomuch that I confidently pronounced it to be my father's ship, the *Fame*, which it afterwars proved to be; though on comparing notes with my father, I found that our relative positions, at the time, gave a distance from one another, of nearly 30 miles, being about 17 miles beyond the horizon, and some leagues beyond the limit of direct vision. I was so struck with the peculiarity of the circumstance, that I mentioned it to the officer of the watch, stating my full conviction that the Fame was then cruising in the neighboring inlet." Vessels thus represented in the air by the unequal refraction of the atmosphere,

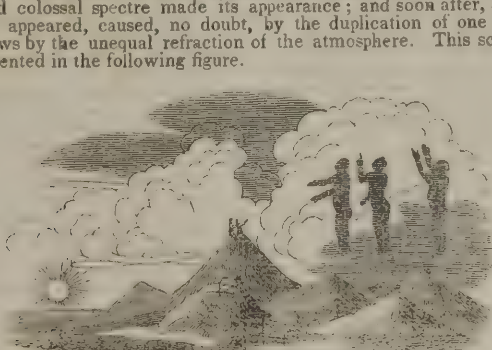
has no doubt given rise to the stories of phantom ships; as, for instance, the superstitious notion of the Flying Dutchman, which obtains general credence among sailors.

Sometimes, sunken rocks and sands appear as if raised above the surface. It was under an illusion of this kind that the Swedes long searched in vain for an island, which had been seen from a distance, as if lying between the coast of Upland and the isles of Aland. Another illustration of the same illusive appearance is afforded by the *fata morgana* of the Italians. A spectator at Messina sometimes beholds the shipping and buildings on the shore of Naples, as if floating in the air. Again, standing on an elevated place in the city of Reggio, commanding a view of the bay, with his back to the rising sun, the spectator may often observe, when the rays form an angle of about 45° with the horizon, the objects on the shore, palaces, castles, and towers, men, horses, and cattle, all vividly painted on the surface of the water. Similar appearances have been frequently presented upon the lakes of Ireland: and with all of these, some legends, as, for instance, the story of O'Donoughoo, who haunts the beautiful lake of Killarney, are connected. As this celebrated chieftain is doomed to ride over the lake on the morning of the first of May, on a horse shod with silver, (an exercise to be continued until the shoes are worn out,) thousands assemble on the shores to see him; and that the phenomenon has been observed can scarcely be doubted; but if so, it is merely the shadow of a man on horseback riding on the shore.

In 1744, an aërial reflection of a troop of horsemen was seen along Souterfell side, by twenty-six persons, two of whom swore to the circumstances witnessed. Advancing as regular troops along the side of the mountain, they moved at a rapid walk, and continued visible for more than two hours. Many divisions followed in succession; and frequently the last but one in a troop would quit his position, and gallop to the front. That these were troops exercising in secret, in preparation for the rebellion which broke out in 1745, is the most probable opinion; and here the unequal atmospheric refraction brought them to the opposite side of the hill.

"It is impossible," says Dr. Brewster, "to study these phenomena, without being impressed with the conviction, that nature is full of the marvellous, and that the progress of science, and the diffusion of knowledge, are alone capable of dispelling the fears which her wonders must necessarily excite even in enlightened minds." It is, indeed, true that man trembles when in the midst of nature's wildest solitude, he beholds troops performing their evolutions on the surface of a lake or on the face of an inaccessible precipice, or if he sees a gigantic image of man himself delineated on the sky, as in the *Spectre of the Brocken* to be now described, or if when in the solitude of the ocean's waste, ships are seen in the air, notwithstanding none are within reach of the eye. As these extraordinary phantasms appear in the character of the real phenomena of nature, a satisfactory knowledge of the causes can alone remove the impressions of supernatural agency.

For centuries past, one of the peaks of the Hartz mountains, elevated about three thousand three hundred feet above the sea, has been celebrated as the site of spectral appearances; but, unfortunately for the lovers of the marvellous, the philosophical investigations of Mr. Haue, in 1797, divested this spot of its high reputation of being the chosen seat of supernatural powers. Long anxious to view the phenomenon, M. Haue had many times ascended the mountain unsuccessfully; but, about four o'clock in the morning of the 23d of May, 1797, as he was awaiting the rising of the sun, the meteor made its appearance. The sky being clear, he saw on a cloud opposite to the rising sun, a gigantic human figure with his face toward him. While, with a feeling not free from superstitious dread, he was gazing on the prodigious spectre, a little accident, otherwise unimportant, quickly dispelled from his mind such idle terrors. Lifting his hand to detain his hat, which a sudden gust of wind threatened to blow away, M. Haue observed the action mimicked by the spectre. Profiting by this hint, he changed his place and attitude, and found that his motions were always imitated by the figure. Being now joined by a person who had accompanied him, a second colossal spectre made its appearance; and soon after, a third figure appeared, caused, no doubt, by the duplication of one of the shadows by the unequal refraction of the atmosphere. This scene is represented in the following figure.



SPECTRE OF THE BROCKEN.

Several very curious instances of refraction are mentioned by Mr. Scoresby, in his "Account of the Arctic Regions." Sailing along the coast of Spitzbergen with an easterly wind, he observed a singular transformation of Charles' Island. It presented the appearance of a mountain in the form of a slender monument, and near it a perfect arch thrown over a valley at least a league in breadth. The scene now shifted with all the effect of a dramatic display, presenting the appearances of towers, spires, castles, and battlements. "Every object," says Mr. Scoresby, "between the northeast and southeast points of the compass, was more or less deformed by this peculiar refraction." From a great number of analogous observations, Mr. S. deduces the following results:

1. That the effects of unusual refraction are most frequent on the approach of easterly winds, and that they occur in the evening or night after a clear day.

2. That the causes of these phenomena are the commingling, near the surface of the sea or land, of atmospheric currents of different temperatures, and the irregular deposition of imperfectly condensed vapor.

SUBSECTION V.—*Thunder and Lightning.*

As regards *electrical* phenomena, it does not comport with the plan of this work to bring them under detailed examination. The identity of *lightning* with the common electricity excited by the machine, was so completely established by our celebrated countryman, Franklin, that no doubt has since existed on the subject. When perfectly dry and pure, atmospheric air is one of the most complete non-conductors of electricity known; but the moment it takes up water in the form of vapor, it acquires the property of being a conductor of electricity. As a mass of visible vapor, that is, a cloud, when floating in a mixed atmosphere of air and vapor, becomes insulated, it is capable of electrical accumulation; and when these derangements of electrical distribution become equalized, the phenomena of *thunder* and *lightning* are produced. We thus behold the phenomena of the electrical machine on a large scale. The interior and the exterior coatings of an electrical jar surcharged with the two opposite forms of electricity, are represented by a cloud and the earth, or two clouds, similarly surcharged; the interposed and non-conducting glass is represented by the intervening and non-conducting air; and the spark and explosion resulting from the union of the two electricities find their counterpart in the lightning and thunder. Like heat and light, the distribution of electricity increases from the poles toward the equator. It is in the intertropical regions alone, that the effects of this energetic agent are fully displayed. It is, however, often manifested with great power in the summer season of temperate climates, especially in mountainous regions.

Thunder, that is, the sound which attends the phenomenon of lightning, is modified in character and intensity by the extent and elevation of the electric clouds, and the physical peculiarities of the country. The rolling sound of thunder is caused by reverberation among the clouds. If the discharge is far distant from the hearer, a deep grumbling noise is produced; if near at hand, an instantaneous crash is perceived. When it occurs over a level country, as there are no objects to produce a reverberation, the sounds consist of a series of regular explosions; but when over a mountainous or broken district, the sound is generally modified into successive claps, irregular both in time and intensity. Thunder, as just remarked, is more frequent as we approach the equator, being totally unknown in the Arctic regions. It is seldom heard at a greater distance than two miles. The distance of an electrified cloud from the place of observation may be estimated approximately, by allowing 1090 feet for each second which elapses between seeing the flash of lightning and hearing the report.

SUBSECTION VI.—*Aurora Borealis.*

The *aurora borealis*, or northern light, which is supposed to have some connection with electricity, is a remarkable luminous phenomenon, which occurs during the night, and most commonly in clear or frosty weather. These *merry dancers* or *streamers*, as they have been called, become more frequent as we approach the poles, it being, indeed, unknown in low latitudes. Mr. Dalton's description of it as seen in England, is exceedingly interesting. His attention was first excited by a remarkably red appearance of the clouds to the south, by which light sufficient was afforded to read at 8 o'clock in the evening, notwithstanding there was no moon or light in the north. "From 9½ to 10 P. M.," he says, "there was a large luminous horizontal arch to the southward, almost exactly like those we see in the north, and there was one or more concentric arches northward. It was particularly noticed that all these arches seemed exactly bisected by the plane of the magnetic meridian. At half-past 10 o'clock, streamers appeared very low in the southeast, running to and fro from west to east; they increased in number, and began to approach the zenith, apparently with an accelerated velocity, when all of a sudden the whole hemisphere was covered with them, and exhibited such an appearance as surpasses all description. The intensity of the light, the prodigious number and volatility of the beams, the grand intermixture of all the primitive colors in their utmost splendor, variegating the glowing canopy with the most luxuriant and enchanting scenery, afforded an awful, but, at the same time, a most pleasing and sublime spectacle. Every one gazed with astonishment; but the uncommon grandeur of the scene only lasted one minute; the variety of colors disappeared, and the beams lost their lateral motion, and were converted as usual into the flashing radiations; but even then it surpassed all other appearances of the aurora, in that the whole hemisphere was covered with it." In Sweden, Lapland, and the polar regions, the aurora borealis is singularly beautiful; and so constant is it during the long winter nights, as frequently to serve the traveller instead of the light of the moon. It was long believed that the aurora is much feebler and less frequent in the southern than in the northern hemisphere, but it is now well established that such is not the fact.

That the aurora is a luminous representation of electricity flowing from the equator to the poles for the restoration of electric equilibrium, is an opinion considered probable by Dr. Farraday. There also seems to be some connection between the magnetic poles and the aurora, it having been observed in Europe that the most elevated point of the aurora is always situated in the magnetic meridian of the place of the observer. It is, likewise, inferred that it has some relation with the temperature of the atmospheric strata in which it is produced. The fact that the aurora can be imitated by passing electricity through a vacuum, causing beautiful streams of light which vary in color and intensity, according to the amount of air present, would seem to imply a common origin.

SUBSECTION VII.—*St. Elmo's Light.*

This is a luminous meteor that frequently settles upon the tops of ship masts, and at the points of spears and other warlike instruments when in motion. The ancients called a single flame of this kind, *Helena*; but when seen in pairs, *Castor* and *Pollux*. It was formerly regarded by mariners to be a visible representation of their tutelar deity, St. Elmo: and hence arose its appellation. When confined to the topmast, it was considered by sailors to be a favorable prognostic; but when it descends the mast, it is regarded as a harbinger of evil in proportion to this descent. Its character as an omen of ill did not escape the attention of Falconer, in his "Shipwreck"—

High on the masts, with pale and livid rays,
Amid the gloom, portentous meteors blaze.

It is generally believed to be an accumulation of electric matter, from the well-known aptitude of a pointed conductor in transferring electricity from a highly electrical atmosphere.

Of a similar nature is the more common meteor, vulgarly called the *Shooting Star.*

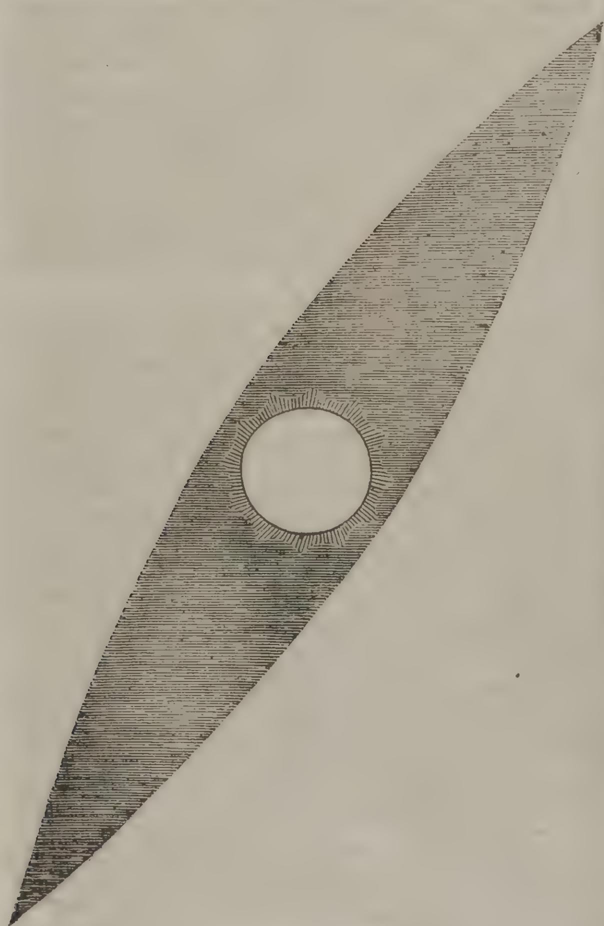
SUBSECTION VIII.—*Ignis Fatuus.*

The *Ignis Fatuus* or *Will o' the Wisp* is a meteor generally produced by the disengagement of phosphoretted hydrogen gas, which inflames at the ordinary temperature of the atmosphere, or, as is supposed by some, by a strongly electrified animal vapor. A flickering and unsteady light, and irregular in its motion, it is often seen hovering over boggy grounds; it sometimes plays over dunghills; and it occasionally appears, to the no small terror of the ignorant, as a lambent flame in church-yards. Among the uninformed peasantry, it has ever been considered the visible representation of an evil spirit, that delights to lead astray the benighted traveller amid bogs and morasses. In the words of Milton—

A wand'ring fire,
Hovering and blazing with delusive light,
Misleads the amazed night-wanderer from his way
To bogs and mires, and oft through pond or pool,
There swallowed up and lost, from succor far.

SUBSECTION IX.—*Zodiacal Light.*

The *Zodiacal Light* may be described as a luminous appearance, seen before and after sunset; it resembles the milky way, but is of a fainter light; its base is always turned toward the sun, and its axis is variously inclined toward the horizon. This pyramidal light, computing



ZODIACAL LIGHT.

from the sun at its base, has a length sometimes of 45°, and at others of 150°. It was accurately described, in 1683, by Dominique Cassini, who gave it its present name. Its cause is generally ascribed to an atmosphere surrounding the sun, on the supposition that when the sun is below the horizon, a portion of this luminous atmosphere will appear above it like a pyramid of light. That the sun has an atmosphere, there is good reason to believe from the circumstance that, in total eclipses, a luminous aurora seems to surround his disc. The obliquity of the sun's equator to the horizon, if this theory is a true one, will of course affect the obliquity of the zodiacal light; and hence about the time of the vernal equinox, it will form a very great angle with the horizon. The latter part of February and the early part of March, has accordingly been found the season most favorable for observing it. Objections, however, have been made to this theory, Regnier being of opinion that it is caused by the refraction of the solar light by the earth's atmosphere.

SUBSECTION X.—*Falling Stars.*

Falling Stars are exceedingly interesting phenomena, which, until within a few years, have not received proper attention. It is not intended to argue the concurrent question, whether a new planetary world is about being revealed to us. It is now proved that they do not originate within our atmosphere, but come from beyond its limits. Particular attention should be paid to these appearances from the 20th to the 24th of April, and on the nights of the 10th, 11th, 12th, 13th, and 14th of November, to ascertain whether, as on several previous occasions, they will recur at these periods.

SECTION VII.—FOREIGN BODIES IN THE ATMOSPHERE.

Foreign bodies are occasionally found in the atmosphere, some being merely suspended in a state of mixture, while others exist in a state of solution.

SUBSECTION I.—*Various Bodies.*

Both in ancient and modern times, we have had *showers of blood, of sulphur, of ashes, of manna,* etc., as well as *red snow.* The nature of these coloring matters has been found to vary much in different instances, being mostly of vegetable origin. Minute lichens and other cryptogamous plants may, by the agency of winds, be transported from a great distance, and be diffused in myriads through the atmosphere. The *showers of blood,* which have at various periods, caused much popular excitation, are now ascribed, as in the case of the red snow of Greenland and the Alps, to the red globules or seeds of the *uredo nivalis,* or to minute red insects. The red excrement of insects has also occasionally given the appearance of drops of blood falling from the air. The *shower of sulphur,* which is rcorded as having occurred at Copenhagen, in May 1646, was doubtless the same as the phenomenon of May 1804; but this last yellow deposit, on analysis, was found to consist of vegetable pollen, resembling the powder of *lycopodium.* A shower of yellow powder was also observed, in 1761, at Bordeaux; but this was immediately recognized as the pollen of some neighboring pine forests, carried up into the air by a violent gale. That small frogs and fishes occasionally descend with rain, is not improbable, as such animals, and even matter a hundred-fold more ponderous, have been raised into the atmosphere by whirlwinds. The color has been occasioned, in other instances, by earthy and metallic matter in a state of very fine powder; and in these cases, the descent is usually accompanied by violent electrical phenomena, analogous to those which almost always attend the fall of Meteoric stones or Aërolites.

A striking example of the showers of dust, which are recorded as having fallen at different times in various parts of the globe, is given by Dr. John Davy.† One of the most remarkable circumstances connected with it, is the extent of surface over which the dust fell, comprising Italy, Malta, Sicily, Sardinia, and perhaps even more distant parts. This occurred, as noted by Dr. Davy, in Malta, on the 15th of May, 1830. "In the morning of that day," he says, "a strong sirocco wind prevailed; the atmosphere was hazy, the sky overcast, of a sooty hue; at eight A. M. the dry thermometer was 69°, the moist 63°. Toward noon, the wind moderated, and at the same time the obscurity of the atmosphere increased; so that the natives became alarmed and apprehensive of some impending calamity, such as an earthquake or something extraordinary. Between one and two o'clock, it became almost calm, with the same state of atmosphere. About that time, I believe, the falling of dust was first perceived. I happened then to be riding into the country, and was surprised to perceive that the rain-drops, of which there were but a few, left a reddish stain on my linen; and on going into a garden, I found the leaves of the plants generally covered with a reddish dust of extreme fineness. The exact time the dust was falling was not ascertained; it probably did not exceed two or three hours. It ceased soon after four P. M., about which time the wind changed to westerly, and the haze diminished. When the dust was falling fastest, and the obscurity was greatest, there was sufficient light to see objects distinctly. The quantity, too, of dust which fell was inconsiderable; what was swept from the deck of the Windsor Castle, a ship of the line of seventy-four guns, then lying an anchor in the great harbor of Valletta, was supposed sufficient to fill two buckets."

SUBSECTION 2.—*Aërolites.*

Aërolites have frequently descended from the atmosphere from the remotest antiquity. It is only within the last half century that they have been carefully observed in Europe and in our own country; but the Chinese and Japanese have paid particular attention to these phenomena, having a descriptive catalogue of the *falls of stones* extending as far back as the seventh century before the Christian era. The origin of these stones, in the present state of our knowledge, is inexplicable. Some, considering aërolites to be the productions of our own planet, imagine them to have been fragments of rocks projected from volcanoes to great height, and which fall back again after having performed several revolutions around the globe. Others suppose them, the possibility of which has been demonstrated by calculation, to be ejected from the volcanoes of the moon, to such a distance as to come within the sphere of the earth's attraction. It is maintained by a third class that they are generated by the combination and condensation of their component parts, previously diffused in the atmosphere in the gaseous form. Others allege that they are detached bodies, moving through the boundless regions of space by virtue of the planetary actions, and that they come in contact with our planet only when its attraction proponderates over their centrifugal force.

It is now generally admitted that aërolites, while in the higher regions of the atmosphere, are often in a state of intense ignition. Traversing the air with amazing velocity, they assume the form of brilliant meteors; and as they approach the earth, they burst with a terrible detonation, followed by a shower of stones. Some of these balls descend with all the disastrous effects of thunder and lightning, destroying animals, breaking through the roofs of houses, and shattering vessels at sea. Evident marks of fusion are generally exhibited by these stones; and as many of them have been picked up while still warm, there could exist no doubt of their being *bonâ fide* aërolites. They are all distinguished by one remarkable similarity. They contain invariably iron cobalt, or nickel, or two or all three of these metals, in union with various earthy substances. Aërolites have been found of every dimension, varying from the weight of a few grains to that of several hundred pounds. The isolated masses of iron of this latter magnitude, which have been seen in various parts of the world, are now generally allowed to be of meteoric origin.

† Notes and Observations on the Ionian Islands and Malta.

SUBSECTION 3.— ry Fogs.

These *Fogs* are those matters, whatever their nature may be, which have been known to spread as a haze over large tracts of the earth's surface. These great fogs or mists have some connection with earthquakes and volcanic eruptions, and also with pestilential diseases. By Noah Webster* it has been shown from historical records that they have existed at many epidemic periods, ever since the darkness that attended the plague of Egypt in Pharaoh's time. During the progress of the Black Death in the 14th century, for example, a thick, stinking mist accompanied the march of this plague. "A dense and awful fog," says one writer, "was seen in the heavens, rising in the east, and descending upon Italy." More recently, as in the years 1782 and 1783, a haze of a pale blue colour spread over the whole of Europe. At the same time, there occurred terrible earthquakes in Calabria and in Iceland. And simultaneously there prevailed throughout Europe, an epidemic catarrh or influenza, affecting not only mankind but likewise other animals. "It will be found invariably true," says Webster, "in every period of the world, that the violence and extent of the plague have been nearly proportioned to the number and violence of the following phenomena—earthquakes, eruptions of volcanoes, meteors, tempests, and inundations." These dry fogs have also been ascribed, but with little show of reason, to the passage of the earth through the tail of comet.

SUBSECTION 4.—*Malaria.*

Of the substances *suspended* and those *dissolved* in the atmosphere, the haze just described may be regarded as intermediate. Among the matters occasionally diffused through the atmosphere, and which appear to be in a state of solution, reference may be made to *Malaria.* This noxious exhalation arises in localities partially covered with water and having a luxuriant vegetation, such as fens and marshes. It is evolved in its greatest abundance and virulence in warm countries; but it also appears in cold and temperate climates, at seasons of the year when the sun is most powerful. Under the latter circumstances, it produces generally the ordinary fever and ague; but on approaching the tropics, and within those limits, it manifests itself under the form of the fatal remittent fever—the well-known scourge of hot climates. With respect to the nature of these exhalations our knowledge is very imperfect; but that the comparative unhealthiness of low, swampy situations, depends upon an admixture of terrestrial emanations with the common atmospheric elements, is obvious, notwithstanding these agents have thus far escaped the researches of the chemical analyst.†

SECTION VIII.—OF THE MEANS OF FORETELLING THE WEATHER.

IF it is true that the inhabitants of a particular locality acquire, by their personal experience, the art of foreseeing the weather, the importance of their availing themselves of all the observations that have been made on this subject, especially the precise knowledge obtained by instruments, can be no longer a matter of doubt. The following remarks, then, in reference to those signs which are true indicators and prognostics of the different changes of the weather, taken chiefly from the "*Maison Rustique du XIX Siècle,*" will not be regarded as here out of place.

SUBSECTION 1.—*Prognostics furnished by Instruments.*

As the barometer usually rises more or less in the morning till 9 or 10 o'clock and falls till 2 or 4 o'clock, to ascend afterwards, any movements contrary to this course indicate a probable change of weather. If the mercury sinks low in warm weather, it is a sign of storm; and if this occurs in good weather, and it continues to fall for two or three days, it presages great rain and probably high wind. In winter, a high rise of the barometer is a sign of cold; and if it falls in cold weather, a thaw is indicated. These changes are generally announced at least a day in advance. The observations of the *thermometer*, and *hygrometer* are of the highest importance, inasmuch as by giving a measure of the variations of temperature and of the degree of humidity, they often point in advance to rain or fog. By means of Daniell's hygrometer, we can ascertain the elastic force of the vapor of the atmosphere with the utmost precision. The weathercock, as an index of the course of the wind, is also a prognostic well worth consulting; for no one, after having lived some time in a particular locality, can be ignorant of the changes of the weather indicated by different winds.

SUBSECTION 2.—*Prognostics furnished by the Heavenly Bodies.*

Observations of the Sun.—The signs of wind are—He rises pale and remains red—his disc is very large—he continues pale, with one or more obscure circles or red rays—he seems concave or hollow. When the sun is accompanied by a parhelion, or seems divided, a great storm is indicated. The *signs of rain* are—The sun rises red or with black stripes mingled with his rays, or becomes blackish—he is obscure, and bathed, as it were, in water—he is placed above a thick cloud, and rises surrounded with a red sky in the east. Sudden rains are never of long duration. It is only when the sky is changed by slow degrees, and the sun, moon, and stars, become gradually obscured, that we have a rain of six hours. The *signs of fair weather* are—The sun rises clear after an unclouded night—the clouds which surround him at his rising, which are often in the form of a circle, take their course to the west—he sets amid red clouds. Hence the popular saying—"*a red evening and a gray morning are sure signs of a fair day.*"

2. *Observations of the Moon.—The signs of wind* are—The moon seems large and has a reddish color—her horns are pointed and blackish—she is encircled by a distinct and reddish halo. If the circle is double or broken, it indicates a tempest. When the moon becomes new, there is often a change of wind. *The signs of rain* are—Her disc is pale—the points of her crescent are blunted. The halo around the moon accompanied by a south wind, portends rain the next day; and when the wind is south and the moon is visible only the fourth night, it foretokens much rain for the month. *The signs of fair weather* are—The spots on the moon are very visible—when full, she is surrounded by a brilliant circle. If her horns, on the fourth day, are sharp, it will be fair till the full moon; and if her disc is very brilliant three days before the change or the full moon, fair weather is surely denoted. A rain followed by fair weather often supervenes upon each new and full moon.

3. *Observations of the Stars.—The signs of rain* are—They seem large and pale—their twinkling is imperceptible, or they are encircled. In summer, if the wind blows from the east* and the stars appear larger than ordinary, a sudden rain is strongly foreboded. *The signs of fair weather and cold* are, when the stars appear in great numbers, and sparkle with the brightest lustre.

SUBSECTION 3.—*Prognostics furnished by the Atmosphere.*

1. *Observations of the clouds. The signs of rain.*—The most fruitful source of meterological prognostics has always been the different appearances and changes of aspect of the clouds; for, as these are the immediate cause of rain and snow, they have, at all times, been looked upon as affording the surest and most direct signs of the changes of the weather. But as this subject was noticed when treating of clouds, its introduction in detail again is deemed unnecessary. If the wind blows in cloudy weather, rain ought to follow. If it begins to rain an hour or two before sunrise, it is quite probable that it will be fair at noon; but if it commences an hour or two after sunrise, it will generally continue to rain during the whole day. A shower after a high wind is a sure indication that the storm is near its end, whence the vulgar saying—"*A little rain lays a great wind.—Signs of fair weather*: when at sunrise the clouds seem to vanish—when small clouds appear to descend, or to go against the wind—when they are white, or the sky has the aspect called *curdled*, the sun being above the horizon.

2. *Observations of fogs.*—Rain is indicated in a day or two, when the fogs appear attached towards the summits of the hills; but a sudden rain may be expected, if, in a dry time, the fogs ascend more than usual. Fair weather is prognosticated if the fogs appear to be dissipated or to descend a little after rain; and fair weather and heat are indicated for the ensuing day, if, after sunset or before sunrise, there arises a whitish fog from waters and meadows. A sign of fair weather for the day, is afforded by the deposition of moisture upon the inner side of panes of glass.

3. *Observations of winds.*—The west or northwest winds, in almost all France, give rain or showers: the south or southwest winds prepare the weather for it. If the clouds move in different directions, or in a course contrary to that indicated by the weathercock, it foreshows a storm.

SUBSECTION 4.—*Prognostics furnished by Vegetables.*

Among the signs of rain, are the bind-weed and the chick-weed of the fields, the rainy marigold, and many other plants, which shut their blossoms at the approach of rain. Hence the chick-weed has received the appellation of *Poor Man's Barometer.*

SUBSECTION 5.—*Prognostics furnished by Animals.*

As the bodies of birds are almost wholly pervaded by air, the organs of respiration being continued into their bones, it is not surprising that they should be more sensible than other animals to atmospheric influences. Hence they are especially consulted by the hunter, the navigator, and all other persons who pass much of their lives in the open air. *Signs of wind:* The aquatic birds collect upon the shore and sport there, especially in the morning—ducks and coots are clamorous and uneasy—ravens sport upon the banks or shoot through the air. When the fishes of the sea and of the fresh water leap frequently above the surface, a storm is presaged. *Signs of a calm:* The play of dolphins upon the water during the storm—the return of the halcyon to the sea before the wind ceases—the coming forth of moles from their holes—the customary singing of the smaller birds. *Signs of rain:* The water-fowl leave the sea for the land, while the land birds, especially geese and ducks, resort to the water and there make great splashing and noise—the crows and ravens gather together and then suddenly disappear—the pies and jays assemble in flocks and make a great uproar—the crows caw in the morning more than usual and in an interrupted manner—the herons and buzzards fly low—the swallows skim the surface of land and water, (for insects now keep near the earth,)—the small birds fly to their nests, neglecting their food—the pigeons keep their cotes—the fowls and partridges roll themselves in the dust and shake their wings—the lark and sparrow sing very early—the owls and peacocks, during the night, cry louder and oftener than usual, etc. The asses bray more than ordinary—the oxen distend their nostrils, look toward the south, and, lying down, lick themselves—the horses leap about and neigh violently—the sheep and goats gambol and butt each other—the hogs frisk about and fight, carrying straws or sticks in their mouths—the cats wash their faces and ears—the dogs scratch the ground with eagerness, and a rumbling noise is heard in their bowels—rats and mice are more turbulent than usual, etc. The frogs and toads croak in the ditches—worms issue in great numbers from the ground—the spiders working little, retire into their corners—the flies are less lively and exceedingly troublesome by their biting—the ants hasten to their hillocks, and the bees to their hives—the gnats sing more than ordinary, etc. *Signs of fair weather:* The kites and bitterns fly with cries—swallows no longer skim the surface, but, as insects now keep in the upper regions, they fly high—turtles coo slowly—the red-breast rises into the air and sings—the wrens sing in the forenoon till nine or ten o'clock, and in the afternoon till four or five o'clock, etc. The gnats and flies, after sunset, play in the air—wasps and hornets appear in the morning, in great numbers—spiders appear in the air and upon plants, spin tranquilly, and extend their webs largely. If spiders alter their web between six and seven in the evening, a fine night is indicated; end if in the morning, a fine day may be expected. If they work during rain, there will soon be fine weather. The activity and industry of the spider would, indeed, seem to be a measure and indication of the fairness of the approaching weather; but should they, for instance in gardens, break off and destroy their webs, and secrete themselves, look out for a continued rain.

"The leech also," says a late English Meteorological Journal, "possesses the peculiar property of indicating approaching changes of the weather in a most eminent degree. In fair and frosty weather it remains motionless and rolled up in a spiral form at the bottom of the vessel; previous, however, to rain or snow, it will creep to the top, where, should the rain be heavy or of long continuance, it will remain for a considerable time—if trifling, it will descend. Should the rain or snow be accompanied with wind, it will dart about with great velocity, and seldom cease its evolutions until it blows hard. If a storm of thunder or lightning be approaching, it will be exceedingly agitated,

* History of Epidemic and Pestilential Diseases.

† This subject has been fully investigated by the author in his work on "The Climate of the United States and its Endemic Influences."

* The reader will bear in mind that the "*Maison Rustique*" applies particularly to the climate of France.

and express its feelings in violent convulsive starts at the top of the glass. It is remarkable, that however fine and serene the weather may be, and to our senses no indication of a coming change either from the sky, the barometer, or any other cause, yet, if the leech shifts its position, or moves about sluggishly, the coincident result will undoubtedly occur within twenty-four hours."

SUBSECTION 6.—*Different Signs and Prognostics.*

The *signs of rain* derived from inanimate bodies, are without number; as, for example, the swelling of wood, the deposition of moisture upon iron and stones, which seem to sweat, the snapping of the cords of musical instruments, the relaxing of the canvass or paper of pictures, the moisture of salt, the appearance of a remarkable circle around the lights, and pools or tanks becoming troubled or muddy. *Signs of a storm:* When the weather is sultry and the soil chaps, a storm at hand is presaged; and also when, in the summer, after the wind has blown from the south for two or three days, the thermometer is high, and the cumulous clouds form large white piles, like mountain heaped upon mountain, with black clouds underneath. If two clouds of this description appear, each in an opposite quarter, it is a still surer prognostic. *Signs of hail and snow:* Clouds of a yellowish white, and which, notwithstanding the wind is high, move slowly. Great storms with hail may be expected, if the sky toward the east is pale before sunrise, and if the thick clouds present refracted rays. In summer white clouds are signs of hail; but in winter, of snow, especially when the atmosphere is mild. *Signs of cold and frost:* The premature appearance of wild geese and other migrating birds—the assembling of the small birds in flocks—the brilliancy of the moon's disc, and the pointed appearance of her horns after the change from full to new—the brightness of the stars—small low clouds flying toward the north—the fall of fine snow, the clouds being piled up like rocks. *Signs of a thaw:* The fall of snow in great flakes during a south wind—the loud cracking of ice—the sun appearing to be immersed in water, and the horns of the moon to be blunted—a changeable wind or its shifting to the south.

In a climate so diverse and variable as ours, none but general observations will of course apply, it being necessary to acquire, from actual experience, a knowledge of local peculiarities.

CHAPTER II.

CLIMATOLOGY, OR RESEARCHES IN ELUCIDATION OF THE LAWS OF CLIMATE IN GENERAL, AND ESPECIALLY THE CLIMATIC FEATURES PECULIAR TO THE REGION OF THE UNITED STATES.

SECTION I.

HISTORY of the Climatology of the United States.—Connection of climate with celestial relation and geographical position.—Local causes which modify climate on the same parallels.—Explanation of the isothermal, isocheimal, and isotheral lines.—Definition of the term climate.—Connection of meteorology with medical science, political economy, the natural history of man, agriculture, and the kingdoms of nature in general.—Influence of malaria on the human constitution.—General physical features of the United States.—Influence of the geological structure of the United States upon its inhabitants.—Correct views of climatology taken by Cabanis, and even by Hippocrates.

PRELIMINARY to the investigation of this subject, a concise account of the past and present state of meteorology in the United States, will not be without value. Climatology, although of the highest interest to man in every conceivable relation of his earthly existence, yet has been strange to say, wonderfully neglected so far as regards the climate of our own country. Indeed, so little effort has been made to keep pace with the progress of kindred branches of science, that the work of M. Volney on the climate of the United States, written more than forty years ago, when this French *savant* made a flying visit through our country, is still quoted by every writer on this topic. So barren of precise data, in truth, is this work, that the author's only instrumental observations consist of a few thermometrical results obtained from a literary gentleman in New York, for which even he made no acknowledgement.

The merit of being the first to establish, on an extensive scale, a system of meteorological observations, with a view to the elucidation of the laws of climate throughout the United States, is due to the late Surgeon General of the United States' Army, Dr. Joseph Lovell, who, in 1819, issued instructions to the medical officers of the different posts to keep regular records of the weather, and to transmit them quarterly to the Medical Bureau at Washington.* In 1820 and 1821, he published the general results of each year; and in 1826, the connected results of the observations for the preceding four years. The first State that followed in this laudable measure was New York, whose academies and other schools established under legislative patronage, have been bound, for many years past, to keep meteorological registers, and make reports of the results to the Regents. In 1836, a liberal appropriation for similar purposes was made by the legislature of Pennsylvania, thus supplying each county in the State with a set of meteorological instruments; and the observations thus made have been reported monthly to a special committee of the Franklin Institute, where they are at all times open for consultation. As Ohio has come, within the last year, into a similar measure, we have now a very extensive district of country dotted, as it were, with points of instrumental meteorological observation. When to these efforts of individual States and those of the medical department of our army, we add the observations made under the direction of the British authorities in their extensive possessions, as well as those of private individuals throughout the continent of North America, it is cheering to those engaged in solving the intricacies of meteorological phenomena to look upon the future.

In this general view of the existing state of climatology in our country, the claims of the present head of the Medical Department of the United States' Army, Dr. Thomas Lawson, as one who has contributed more than any other toward relieving us as a nation from the odium of lagging behind in the present onward march of meteorological science, must not pass unnoticed. It was under his official direction that the author of this work, then an officer of the Medical Corps of our Army, undertook the investigation of this subject in the "*Army Meteorological Register,*" and the "*Statistical Report on the Sickness and Mortality in the Army of the United States,*" embracing a period of twenty years, (1819 to 1839,) both of these volumes being published officially by the War Department. Subsequently, the author having compressed these volumes into one-fourth their original compass, by divesting them of statistical details, and having added thereto such general deductions as more extended investigations enabled him to make, he published a work on his own responsibility, entitled "*The Climate of the United States and its Endemic Influences.*" It is upon the researches contained in these several works, that much of the present volume is based. Prior to the appearance of these works, we possessed no treatise founded on facts in regard to the climate of the region that we inhabit; but the materials employed in their composition are authentic—data which have required years to collect, and years to collate and digest. Unlike all other treatises on the same subject, which are generally loosely written and made up of the most vague and general statements, the deductions of these volumes are based upon precise instrumental observations. The author may be permitted to make the following quotation here from his preface to "The Climate of the United States and its Endemic Influences":—"The design of this work is to exhibit a connected view of the leading phenomena of our climate, both physical and medical, comprising a condensation of all the author's observations on the subject. * * * The chief objects intended to be accomplished are to present, in PART FIRST, a classification of the principal phenomena of our climate, *physically* considered; and to attempt, in PART SECOND, to trace out the *medical* relation of these laws, thus establishing in both a classification of climates having for its basis observation. * * * In relation to climate, nearly all our facts stand isolated; and inasmuch as to render such data valuable, it is necessary that they be collated, thus determining their relations to one another and to general laws, the attempt has been made to present a systematic arrangement so far as the facts collected will warrant, leaving the further prosecution of the subject to a period when new data shall have been accumulated." In the present work, however, the author's labors will be restricted to physical climate. Having before him a mass of authentic matter in relation to the climatology of our country, from the oldest settlements on the Atlantic shores to the farthest outposts of civilized occupation, even to the coasts of the Pacific, he will endeavor to determine the relations to one another of these isolated facts; and comparing these results with the general laws of climate, he will demonstrate their harmony throughout the globe.

The temperature of the atmosphere is derived from the heating of that portion of it in contact with the surface of the earth, which has received and absorbed the incident solar rays. But the superficial temperature of the earth is connected with two classes of causes, viz., those resulting from celestial relation, and those depending on geographical position. The former, which may be called the *primary* constituents of climates, result from the globular figure of the earth, its diurnal motion upon its axis, and the obliquity of its motion in an elliptical orbit in regard to the plane of the equator. The distribution of heat and light is much affected by the globular figure of the earth, inasmuch as when parallel rays fall upon a globe, the number of such rays falling perpendicularly, as at the equator of our earth, occupy much less space, than an equal number of the same rays, when, as in our polar regions, they strike the globe obliquely. The earth's revolution on its axis also greatly influences the distribution of heat and light, producing the grateful vicissitudes of day and night, and the innumerable minor vicissitudes of temperature. To the third great primary cause regulating the distribution of heat and light over the globe—the oblique motion of the earth in its orbit—we owe the endless variations of seasons in different latitudes. Had the axis of the earth been perpendicular to the plane of its orbit, the sun would have been always vertical to the same places; and hence, while the equatorial regions would have been parched with intolerable heat, much of what is now the fairest portions of the globe—the seats of literature and the arts—would have known only sterility and desolation. But from the simple though stupendous contrivance of the inclination of the axis, every part of the earth's surface, between the latitudes of 23½° north and south from the equator, is, during the annual revolution of the earth round the sun, exposed in turn to its perpendicular influence. Thus has the fervor of a tropical sun been rendered less oppressive, while the limits of the temperate regions have been so extended that the abodes of animated beings cover the largest portion of the globe. Now as the earth's orbit is not a circle, but an ellipse, and as the earth is consequently at Christmas about three millions of miles nearer to the sun than at Midsummer, it may, at first view, be inferred that the temperature of the southern hemisphere, which, during our winter, is directly exposed to the sun, would be materially influenced by this greater proximity. This, however, is not the case; for, according to Sir J. Herschel, "the greater proximity of the sun in the winter is exactly compensated for by the earth's more rapid motion, and thus an equilibrium of heat is, as it were, maintained." Now, if the phenomena of terrestrial temperature depended solely on this class of causes, climates might be classified with mathematical precision; but the effects produced by solar heat are so much modified by local causes, that the climatic features of any region can be determined only by observation.

It is thus seen that the effect of the sun's rays on the solid mass of the earth, is one of the main causes which determine the temperature of a locality. The caloric received by the earth at its surface is subjected to two processes: by the one, *conduction*, it is transmitted into the interior; and by the other, *radiation*, the superfluous heat is thrown from its surface. The daily impressions of heat which the earth receives, follow one another, by the laws of conduction, into the interior of the mass; and the heat thus accumulated in this reservoir, flows from one part to another, seeking to maintain its equilibrium. As the equatorial parts are most heated by the sun, there is an unceasing conduction of heat from this region to other portions of the sphere; and as caloric is constantly radiated from all parts of its surface, the polar regions which receive little in return from the sun, produce a constant waste. There is thus a kind of circulation of caloric, the perpetual dispersion from the

*It is due to the Hon. John C. Calhoun, who was Secretary of War at the period of the establishment of the Medical Bureau of the Army, to state that in his "Life," recently published, it is claimed that these meteorological observations had their origin exclusively in his enlarged views.

polar regions being supplied by as constant an internal flow from the equator toward each pole.

Among the *secondary* constituents of climate, or the geographical or local causes, the following may be regarded as the principal:—1. The action of the sun upon the surface of the earth ; 2. The vicinity of great seas and their relative position ; 3. The elevation of the place above the level of the sea ; 4. The prevalent winds ; 5. The form of lands, their mass, their prolongation toward the poles, their temperature and reflection in summer, and the quantity of snow which covers them in winter ; 6. The position of mountains relatively to the cardinal points, whether favoring the play of descending currents or affording shelter against particular winds ; 7. The color, chemical nature, and radiating power of soil, and the evaporation from its surface ; 8. The degree of cultivation and the density of population ; 9. Fields of ice, which form, as it were, circumpolar continents, or drift into low latitudes.

It is these causes that determine the deviations of the *isothermal*, *isocheimal*, and *isotheral* lines from the same parallels of latitude. As already explained, the isothermal curves represent lines drawn upon a map through all the places on the globe having the same mean annual temperature ; and these lines are by no means, as might have been expected, regular. Were two travellers, for example, to set out, the one from London and the other from Paris, visiting all the places having the same mean annual temperatures, it would be found that the lines of their routes would not only deviate from the parallels of latitude, but would not be parallel to each other. Thus the isothermal line or mean annual temperature of Edinburgh, Scotland, strikes the Atlantic coast of North America twelve degrees farther south. Hence the former division of the surface of the earth into five zones, as regards its temperature, has been superseded in scientific inquiries, by a more precise arrangement. As the places having the same mean annual temperature are connected by isothermal lines, the spaces between them are called isothermal zones. While in this arrangement are classed together the mean temperature of the *whole* year, the application of the same principle to any portion of the year, as the mean winter and summer temperatures is equally obvious. Thus lines drawn through places having the same summer temperatures, are denominated *isotheral*, and those through points having the same winter temperatures, *isocheimal* curves. The importance of this classification, more especially as places having the same mean annual temperature often exhibit great diversities in this respect, will be strikingly apparent when we come to consider the climatic character of a particular country.

By the ancients, the word *climate*, derived from the Greek verb, κλινω, *to incline*, was applied to signify that obliquity of the sphere with respect to the horizon from which results the inequality of day and night. The surface of our globe, from the equator to the arctic circle, was distinguished by that great astronomer and geographer, Ptolemy, into climates or parallel zones, corresponding to the successive increase of a quarter of an hour in the length of midsummer day. These zones within the tropics, are nearly of equal breadth ; but, as the higher latitudes are approached, they contract very much ; and consequently they were here reckoned by their doubles, answering to intervals of half an hour in the extension of the longest day. The first rude mode of forming a division of the earth into climates consisted in determining them by the species of animals and plants produced in each. The negro, the rhinoceros, and the elephant, for example, were considered as characteristic of the torrid zone. Then followed the division into five *zones* and their denominations, or the mode adopted by the ancient geographers of distributing the earth's surface into twenty-six parallel bands or *climates*, both of which, until the invention of the thermometer gave more precise information, were supposed to indicate, with sufficient exactness, the differences of the temperature of each region.

The ancients believed that at the equator there existed an impassable zone of scorching heat, and that although the temperate zone of the southern hemisphere might contain inhabitants, yet that this burning intervening zone precluded all communication. This opinion of Aristotle was supported by Pliny, who makes the following observation :—"The temperature of the central region of the earth, where the sun runs his course, is burnt up as with fire. The temperate zones which lie on either side can have no communication with each other in consequence of the fervent heat of this region." Until the time of Christopher Columbus, this theory was not wholly disproved by modern discovery.

It is thus seen from the preceding remarks, that in the investigation of the laws of climate, a range of subjects so multifarious as to comprise almost every branch of natural philosophy, is embraced ; but its true province is properly restricted to a general view of these subjects, which, if based on legitimate deductions of observed phenomena, should enable us to reduce the infinite variety of appearances presented to us in nature, to a few general principles. It is by means of this generalization that the subject will be elevated to the dignity of a science. Climate comprises not only the temperature of the atmosphere, but all those modifications of it which produce a sensible effect on the physical and moral state of man, as well as on all other organic structures, such as its serenity, humidity, changes of electric tension, variations of barometric pressure, its tranquility as respects both horizontal and vertical currents, and the admixture of terrestrial emanations dissolved in its moisture. Climate, in a word, constitutes the aggregate of all the external physical circumstances appertaining to each locality in its relation to organic nature. "To observe," says Professor Rostan, "the simultaneous effects of light, heat, electricity, of the winds, &c., on the organic productions of the different zones of the earth, to explore the nature of this earth, to deduce from this knowledge the influence which they exercise on the physical and moral state of man, such is the wide field which climates present to our investigation."

Considering the vast importance of this subject to human welfare, it is lamentable to contemplate its meagerness in the advanced state of knowledge in the nineteenth century. Even at the present day, one writer regards climate as differing only with the distance of parallel zones from the equator or the poles : another, as dependent on the internal heat of the globe ; a third, as merely a tabular arrangement of the courses of winds, of the quantity of rain, and of thermometric, hygrometric, and barometric degrees ; while a fourth, supposing himself in advance of the age, refuses to admit that climate is materially modified by any causes other than latitude and local elevation. And there is a fifth, who has recently put forth the opinion that were the equatorial deserts and the temperate regions bordering on the polar, brought under cultivation, the seasons would become equalized, and thus would man realize the millenium.

Reference has already been made to the connection of meteorology with medical science, political economy, the natural history of man, agriculture, and the kingdoms of nature in general. The natural history of man, however, which would, of itself afford matter for a volume, must be wholly excluded from this work ; but the influence of climate on vegetation will be illustrated at some length. In agriculture, England has been, and to a certain extent still is, our principal school of instruction ; but her lessons must be corrected by observing the difference of climate and collateral circumstances. To effect this purposee, a comparative view of the meteorology of the two countries would avail much. But the science of meterology concerns more particularly the horticulturist ; for agriculture has for its object the fertilization of the soil and the growth and nourishment of indigenous plants, and such as have, by a long course of treatment, become inured to the climate ; while horticulture aims not only at a knowledge of the constitution of soils, but aspires to the preserving and propagating of exotic vegetation.

The connection between meteorology and medical science is, in truth, highly important. From the days of Hippocrates, the father of physic the records of medical philosophy demonstrate that the phenomena of life are not the result of original organization only ; but that the moral, intellectual, and physical capacities of man are subject to the influence of these causes, the aggregate of which constitute climate. This doctrine receives an apposite elucidation in the corporeal degeneration induced by *malaria*. So deep and pervading are the effects of this subtle poison on the indigenous inhabitants of marshy districts, in warm climates, that the energies of the system are sapped, and premature decrepitude induced ; and when subjected to these baneful exhalations, through successive generations, the mind becomes torpid and embecile, the moral sentiments debased, and the stature and symmetry of the body deteriorated. "Let us," says Macculloch, "turn to Italy : the fairest portion of this fair land are a prey to this invisible enemy, its fragrant breezes are poison, the dews of its summer evenings are death. The banks of its refreshing streams, its rich and flowery meadows, the borders of the glassy lakes, the luxuriant plains of its overflowing agriculture, the valley where its aromatic shrubs regale the eye and perfume the air, these are the chosen seats of this plague, the throne of malaria. Death here walks hand in hand with the sources of life, sparing none ; the laborer reaps his harvest but to die, or he wanders among the luxuriance of vegetation and wealth, the ghost of man, a sufferer from his cradle to his impending grave ; aged even in childhood, and laying down in misery that life which was but one disease. He is even driven from some of the richest portions of this fertile yet unhappy country : and the traveller contemplates at a distance deserts, but deserts of vegetable wealth, which man dares not approach,—or he dies." Macculloch gives a deplorable picture of the degeneracy produced in man by a residence of successive generations in some of the malarial districts of France and Italy. Young women, before twenty, have often the aspect of fifty, while in men the age of forty is equivalent to sixty in healthier climates. Not only does the stature become reduced, but deformities are frequent. In our own country, along the frontiers of Florida and the southern borders of Georgia, as witnessed by the author, as well as in the low-lands of our southern States generally, where,

> "In florid beauty, groves and fields appear,
> Man seems the only growth that dwindles here,"

may be seen deplorable examples of the physical, as well as mental and moral, deterioration induced by this cause. In earliest infancy, the complexion becomes sallow, and the eye assumes a billious tint. Advancing toward the years of maturity, the growth is arrested, the limbs become attenuated, and the viscera engorged. Boys of fifteen years may be seen bowed down with premature old age—a mere vegetating being, with an obstructed, bloated, and dropsical system, subject to periodical fevers, passive hæmorrhages, and those other forms of disease which follow in the train of malaria. In the Pontine marshes of Italy, the residents have the appearance of walking spectres. The moral and intellectual faculties become degraded. In the Maremma of Tuscany, absolute idiotism is common. The picture drawn by Monfalcon of the moral condition of the people in these pernicious districts is truly frightful. In the catalogue of their vices, he names universal libertinism, abortion, infanticide, drunkenness, a disregard of religion, and while their murders are common, a large proportion are those of premeditated assassination. It is also worthy of remark that while the deaths are increased and the mean duration of life diminished, the ratios of marriages and births are augmented, it being not uncommon for one woman to have had three, four, or even five husbands. What a commentary is this on a pernicious climate !

That the continued operation of these endemic influences would ultimately depopulated the country, might be naturally supposed. Observation, however, has taught us that here, as in epidemics which cause great mortality, the population is only temporarily diminished ; for as the means of subsistence for those who survive have become more abundant, the void is filled up in a few years by a much greater annual average of marriages and consequently of births. In addition to which, as the means of sustenance and employment in low and alluvial regions, are more abundant than in barren and mountainous districts, the excess of deaths over births is equalized by the influx from more healthy parts. This statement is well illustrated by the following statistical table, furnished by M. Bossi, Prefect of the Department of Ain in France, which he has divided into four zones in accordance with its topographical features :

Locality.	One death annually to inhabitant.	One marriage annually to inhabitant.	One birth annually to inhabitant.
In the hilly districts,	38.3	179	34 8
Along the banks of rivers, &c.,	26 6	145	28 8
In cultivated grounds,	24 6	133	27 5
In marshy places, &c ,	20.8	107	26.1

It is not, however, intended here to point out the influence of climate upon the animal economy : but this example is adduced merely to show that the complete development of the mental, moral, and physical attri-

butes of man, even when nature has bestowed a perfect organization, is made to depend upon the physical agents which influence those functions. Another case in point is afforded by the history of a recent epidemic, (*cholera asphyxia*,) which, in its wide diffusion, threatened to depopulate vast tracts of the earth's surface; but which, doubtless owing to great meteorological changes, notwithstanding inappreciable by our eudiometric instruments, suddenly ceased its ravages, and left, like many other destructive pestilences in preceding ages, scarce a trace behind but the terror of its name.

It will be seen, in considering the natural history of man, that he is exposed to the agency of many causes, which either retard or promote the development of his mental, moral, and physical attributes. As in the corporeal structure, different effects result from the dry and restless air of the mountain, compared with those evidenced in the moist and sluggish atmosphere of the valley: so, as regards the mental manifestations, the observation of the poet, GRAY, is philosophically correct—

> An iron race the mountain cliffs maintain,
> Foes to the gentler manners of the plain.

That the physical frame is not independent of external causes, and that the moral and intellectual phenomena of man are not independent of the former, are opinions that rest upon conclusive evidence.

The Physical Features of the United States.

As the climate of every region has an inseparable relation with its physical characters, it follows that in the investigation of its climatic features, a geographical description becomes an essential preliminary; but in the present instance, the country to be described is of so vast an extent as to preclude anything beyond the most general outlines—a description which will, however, more especially as many of the physical features of the United States have already been brought under notice, be sufficient for the purpose designed. It was well remarked by MATE-BRUN, that "*the best observations upon climate often lose half their value for the want of an exact description of the surface of the country;*" and, accordingly, the author will now present an outline, as complete as his limits will allow, of the physical features of the vast region stretching from the Atlantic to the Pacific Ocean, and from the Gulf of Mexico to the inland seas on our northern frontiers.

The United States are bounded on the east by the British Provinces of New Brunswick and the Atlantic Ocean; on the north by the Russian and British Provinces; on the south by the Gulf of Mexico and the Texan and Mexican Republics; and on the west by the two states just named and the Pacific Ocean. This vast region, comprised within the meridians of 67° and 125° W., extending on the Atlantic side from below 25° to 49° N. lat., and on the Pacific side from 42° to 54°, covers a superficial area of 2,300,000 square miles. Of this tract, the frontier line is about 10,000 miles long, of which about 3,600 are sea, and 1,200 lake coast. From the Atlantic to the Pacific, across the centre of the United States, the distance is about 2,500 miles; and its greatest breadth from north to south, is nearly 1,400 miles. These boundaries constitute a territory of vast extent, including the larger part of what is valuable and productive in this part of the continent.

The portion of this immense tract which demands more especial consideration, as being the region in which the meteorological observations have been chiefly made, is that actually within the limits of the organized States and Territories. This region is bounded by a line running north from the Sabine to the Missouri, and following that river to the mouth of the White Earth River, near our northern boundary line. This tract is estimated to contain 1,300,000 square miles.

The territory of the United States is traversed by two great systems of mountains, by which the country is distinctly marked into three natural divisions, viz., the Pacific Region, the Mississippi Valley, and the Atlantic Table-land and Plain. Of these two mountain systems, the more lofty and extensive is that in the western part of the continent, known under the various names of Rocky, Oregon, and Chippewyan. It is a prolongation of the Mexican Cordilleras, and extends to the Arctic Sea. The elevation of the base above the level of the ocean is about 3,000 feet, and the average height of the summits above the base is perhaps 5,000 feet, while some, it is estimated, reach an altitude of 8,000 or 10,000 feet. These mountains are 500 or 600 miles from the Pacific. Farther west is the range of the Pacific coast mountains, which stretch northward from California into the Peninsula of Russian America. They are 70—80 miles from the coast, and their highest summits are from 10,000 to 18,000 feet. These peaks, like some of those of the Rocky Mountains, are covered with snow, and ascend far into the region of perpetual congelation. East of the Rocky Mountains are the Black Hills, stretching north-east and south-west between the Upper Platte and Missouri. The Ozark Mountains, which lie about midway between the Rocky Mountains and the Alleghanies, extend from the Rio del Norte of Mexico to the vicinity of the Missouri. In some places they attain an altitude of 3,000 feet, but their mean elevation is much less.

The Alleghany or Apalachian system designates the whole series of mountains near our eastern coast, which might be more appropriately named the Atlantic system. It consists of four independent mountain groups, crossing the country in the same general direction, from N. E. to S. W., each obviously separable from the others by strongly marked external features, no less than by their geological structure. This system is less a chain of mountains than a long *plateau*, crested with chains of hills, separated from each other by wide and elevated valleys. The mean altitude is perhaps 2,500 feet, of which not more than one half consists of the height of the mountain-ridges above their bases, the adjacent country having an equal elevation above the sea. These parallel mountain-chains rise on the vast tract of table-land, which occupies the western part of the Atlantic States and the eastern portion of the adjoining States of the Mississippi valley, about midway between the Mississippi and the Atlantic. The group in New England, which passes through New Jersey into Pennsylvania, consists, as well as the Chippewyan, almost wholly of *primary* rocks, chiefly of the stratified class. Mount Washington, the most elevated summit, attains an altitude of 6,428 feet. In the Blue Ridge group, pursuing the general south-west course from Maryland to Alabama, no rock of genuine primary character has yet been found, but formations principally of the oldest non-fossiliferous secondary group, or such as formerly would have been named *transition*. In this range, the Black Mountain in North Carolina, which has an elevation of 6,476 feet, is the highest summit. The next group, lying west of the Blue Ridge and continuing parallel with it to Alabama, has a *secondary* formation, which, belonging to the oldest fossiliferous groups, contains no rocks as recent apparently as the bituminous coal series. The third group, which lies to the west and north-west of that last described, presents little uniformity in its course; but when it has the character of ridges, the general direction is parallel. It is also composed of *secondary* formations, consisting of vast piles of nearly horizontal strata, rising from a plain intersected by innumerable deep valleys of denudation—a construction apparently due to causes which seem to have removed part of the high plateau on which they rest, rather than to direct uplifting forces, such as appear to have elevated the more irregular and convulsed systems of the other two parallel mountain ranges, as well as the group in New England. In this triple division south of the Hudson, the eastern may be considered as destitute of any coal formation—the middle as embracing the strata of the anthracite—and the western as containing the vast bituminous coal formation.

The face of the country consequently presents the variety of plain, mountain, valley, and table-land, having primitive, transition, secondary, and alluvial formations. From New Brunswick to the mouth of the Hudson, with a trivial interruption in Connecticut and in the peninsula of Cape Cod, the sea washes a coast of primary rocks often presenting bold projecting cliffs. This region, as far to the north-west as the St. Lawrence river, consists of primary rocks, if we except three narrow belts of secondary strata. This primary region, following the course of the Highlands, as just described, extends into Pennsylvania, and then continues, under formations of a more ambiguous character, as far as Alabama, having for its eastern boundary the tertiary and secondary cretaceous strata of the Atlantic Plain, and for its western, the great valley lying at the base of the Blue Ridge, and farther to the south-west one of the parallel mountain groups. The great secondary deposite spreads over the western parts of New York, Pennsylvania, and Virginia, and occupies nearly the whole surface of the Western and Southern States. On the north-west, it follows the shores of the great lakes, losing itself in the alluvial of the great basin of the Mississippi, and extending, in all probability, west of the Mississippi to the foot of the Rocky Mountains. The alluvial deposites cover vast tracts, the most considerable being that interposed between the Atlantic shore and the Alleghany mountains. This extensive level tract, little elevated above the level of the sea, and gradually widening from a few miles in breadth in the north to nearly 200 miles in the south, has been appropriately named the ***Atlantic Plain***. A ledge of primary rocks, over which the rivers fall, and to which in the northern section the tide penetrates, marks very distinctly the western limits of this tract, along which undulating line are found Trenton, Philadelphia, Baltimore, Georgetown, Fredericksburg, Richmond, Smithville, Camden, Augusta, Milledgeville, and Columbus.* The fact, by the way, that nearly all the principal cities of the Atlantic States have arisen upon this boundary, from the obvious motive of seeking the head of navigation, affords a striking example of the influence of geological causes in distributing population, and thus determining political relations. At Columbus, the ledge recedes to the north-west through Alabama and Mississippi, until the Atlantic Plain is merged into the valley of the Mississippi. Among the physical features which characterize this alluvial zone, which slopes gently down to the ocean, are extensive morasses and swamps, sluggish streams, and wide arms of the sea penetrating far inland. It is composed of tertiary and secondary cretaceous deposites, the former consisting of alternating beds of sand and clay, and sometimes marl, all abounding in marine fossil shells. This tertiary formation as distinguished by the four epochs, termed *eocene*, *miocene*, *older*, and *newer pliocene*, would, did space allow, admit of some interesting observations. As the alluvion brought down by the mighty rivers into this tide-water region, is of a humid nature abounding in organic remains, effluvia or miasmata noxious to man are here copiously generated.

"The surface of this plain," says Professor Rogers, "is everywhere scooped down from the general level to that of the tide by a multiplicity of valleys and ravines, the larger of which receive innumerable inlets and creeks, while the smaller contains marshes and alluvial meadows. The whole aspect of the barrier of primary rocks forming the western limits of this plain, forcibly suggests the idea that at a rather lower level, they once formed the Atlantic shore, and that they exposed a long line of cliffs and hills of gneiss to the fury of the ocean; a survey of the plain just described as strongly suggests the idea that all of it has been lifted from beneath the waves by a submarine force, and its surface cut into the valleys and troughs it presents by the retreat of the upheaved waters."

The great and magnificent central basin of North America, which spreads from the Alleghanies to the Rocky Mountains, and from the Gulf of Mexico to the Arctic sea, is comprised only in part within the United States; but this section constitutes the most fertile and valuable portion of this vast central plain, which including the valley of the St. Lawrence, embraces an area estimated to contain 3,250,000 square miles. On its northern borders, where winter holds perpetual sway, vegetable life expires or survives only in some species of mosses and lichens. South of these dreary wastes, stunted trees begin to appear, forming gloomy and desolate forests; and it is not until we reach the fiftieth parallel, that the eye is cheered with the vegetation known in the temperate zone. Proceeding still farther south, we ultimately discover, in the valley of the Mississippi, the palms and splendid foliage of the tropics,—a land already peopled by millions, and one destined, as a necessary consequence springing from natural adaptation, to nourish upon its fertile bosom multitudes as countless as on the teeming plains of India and China. A characteristic feature of this immense basin of the Mississippi and Missouri, is the vastness of its level surface, covered with primeval forests or spreading in vast savannahs, unless where encroached upon by the rapidly advancing tide of human colonization. Its tracts of fertile lands, with its great and navigable rivers terminating in one main trunk, open to it prospects of opulence and populousness to an extent incalculable. In this region, man is every where occupied in opening new lands, in building houses, in founding cities, and in subjugating nature.

* The term *Atlantic Slope* ought to be applied to the region which, commencing with this abrupt limit of the Atlantic Plain, extends gently upwards to the base of the mountains.

That this immense plain is destined to become the seat of a mighty empire, is a result that will inevitably follow, unless some convulsion of nature, as has been suggested, may cause the ocean-lakes on our Canadian boundary to overwhelm it with a catastrophe more formidable than the deluge of Deucalion. The *possibility* of this event is sufficiently obvious, when we consider that Lakes Superior, Huron, and Michigan, have a mean depth of 1000 feet, and that the surface of these interior seas is elevated more than 300 feet above the level of the Mississippi basin. Now should this intervening barrier suffer disruption from volcanic agency, (of which force there are not unfrequent indications in the valley of the Mississippi,) the devastation that would sweep these plains would find no parallel in the history of our globe since the Noachian deluge.

The general features of the vast northerly regions of America are little varied. Few mountains rise above this savage and icy plain, which is bleak and ever chilled beneath the influence of an arctic sky. At the heads of the Arkansas, Platte, and Yellowstone, is also an arid and sandy tract, so destitute of vegetable life that it has received the name of the American Desert. Having, however, some streams at certain seasons, and being not entirely destitute of plants, the utter sterility of the burning deserts of the eastern continent is not presented.

Between the Alleghanies and the Mississippi, the surface, notwithstanding it is broken into hills, presents the most fertile territory of the United States. The Alleghany or Apalachian table-land, which extends from the great lakes into Alabama, lying about equi-distant from the Atlantic and the Mississippi, has a mean height of about 1000 feet; but in some places, it is much more elevated. Upon this plateau arise the crests of the Alleghany system. Between the sources of the Platte, Arkansas, and Missouri, and the range of the Oregon mountains, lies a table-land still more elevated.

But one of the most striking characteristics of the physical geography of the United States, and which, it will be seen, induces the most remarkable modifications of climate, is the existence of those great inland basins of water which lie on our northern frontier. Of so vast an extent are these ocean-lakes, that one of them, (Lake Superior,) has a circuit, following the sinuosities of the coast, of 1,750 miles. The basin of the St. Lawrence is truly a region of "broad rivers and streams," containing, it is estimated, an area of 400,000 square miles, of which 94,000 are covered with water. From the western extremity of Lake Superior to the gulf of St. Lawrence, the distance is about 1,900 miles. These ocean-lakes have been estimated to contain 11,300 cubic miles of water,—a quantity supposed to exceed more than half of all the fresh water on the face of the globe. The deepest chasms on the surface of either continent are presented perhaps by the depression of these lakes; for though elevated near 600 feet above, the bottom of some is as far beneath, the level of the ocean. Lakes Huron and Michigan, which have the deepest chasms, have been sounded to the amazing depth of 1,800 feet without discovering bottom.

The following table, which gives the mean length, breadth, depth, area, and elevation of these several collections of water, is taken from a recent report made by Douglas Houghton, Esq., State Geologist of Michigan:—

	Mean length *miles.*	Mean breadth *miles.*	Mean depth *feet.*	Elevation above the level of the sea, *ft.*	Area in square miles.
Lake Superior,	400	80	900	596	32,000
Green Bay,	100	20	500	578	2,000
Lake Michigan,	320	70	1000	578	22,400
Lake Huron,	240	80	1000	578	20,400
Lake St. Clair,	20	18	20	570	360
Lake Erie,	240	40	84	565	9,600
Lake Ontario,	180	35	500	232	6,300
River St. Lawrence,			20		940
			Aggregate,		94,000

In the physical and economical geography of the United States, the rivers form an equally important characteristic. Indeed the physical features of America generally have been cast in large forms. In the Eastern States, the rivers, as they all arise from the chain of the Alleghany, cannot, even by a winding course, attain any great length; but it is in the immense basin of the Missouri-Mississippi that we find a system of rivers, constituting her grandest natural features, which, reaching from the Alleghanies to the Rocky Mountains, is unequalled in extent even by the Amazons, and rivalled by none in the world in regard to the benefits destined to be derived from it as a medium of commercial intercourse. The Mississippi and Missouri, which stretch their hundred giant arms over all that immense tract between the Rocky and Alleghany mountains, constituting the southern slope of the vast central plain of North America, are the mightiest of these rivers. The Missouri has its origin in the Oregon mountains, not more than a mile from some of the sources of the Columbia. Its extreme length to the Gulf of Mexico is 4,500 miles, of which 3,800 are navigable. The next most important tributary is the Ohio, which gathers up the waters of one of the most fertile and cultivable regions of the globe. The whole region drained by this noble river comprises an area of 200,000 square miles, rich in the most useful productions of nature, animal vegetable, and mineral, and fortunate in the advantages of a mild and salubrious climate. The Arkansas exceeds the Ohio in dimensions, but a considerable part of its course is through barren, sandy tracts. In the dry season it is shallow, disappears in some parts, or leaves only stagnant pools. Even its floods are so uncertain, and its rise and fall so rapid, that it is almost useless for navigation. Although its estimated length is 2,500 miles, steamboats ascend with difficulty to Fort Gibson, 420 miles. As regards salubrity, the lower Mississippi has been ever distinguished for violent epidemic visitations—diseases indissolubly connected with climate, and more especially with the influence of soil; and the region west of this southern portion, notwithstanding the mortality may be lower, exhibits an equal degree of the prevalence of disease.

From the shores of the Atlantic to the Mississippi, there is presented an immense natural forest, interspersed with open and naked plains, called *prairies*, which are numerous west of the Alleghanies, but very rare on the Atlantic side. The country west of the Mississippi is comparatively lightly wooded; and in the arid and desert plains, occupying a breadth of 300 or 400 miles, only a few trees are seen along the margins of the rivers. In that portion of the United States, which is inhabited, the lands cleared and cultivated do not probably exceed one-tenth part of its surface.

Influence of the Geological Structure of the United States upon its Inhabitants.—When speaking of the rocky barrier constituting the western limits of the Atlantic plain, reference was made to the influence of geological causes on social organization. "It is perfectly apparent to geologists," says Professor Silliman, "that the scenery of a country is not more exactly stamped by its geological formations than are the manners and employments of its inhabitants. The bleak hills and long winters of *New England* are unfavorable to the most extensive and profitable agricultural pursuits, while the extensive and deeply indented seacoasts, abounding with harbors, headlands, rivers, and inlets, naturally produce an impulse toward the ocean, which, conspiring with the original adventurous character of the population, sends them roving from the Arctic to the Antarctic Circle, till the wide world is laid under contribution by their enterprise. Their numerous streams and waterfalls furnish the cheapest means for moving machinery, and thus manufactories spring up wherever, in their expressive phraseology, there is *water-power;* and steam supplies local deficiencies of moving force. Ingenuity, conspiring with a general system of education, is excited under such culture to produce numerous inventions, and hosts of young men seek their fortunes successfully abroad as mechanics, seamen, traders, instructers, and politicians, who thus act powerfully, and, we trust, beneficially on other communities.

"The immense tracts of rich alluvium in the *Southern States*, the mildness of the climate, the coasts less abounding with safe inlets, and often modified by the action of the existing ocean, with a population not originally commercial, give a decided impulse to a vast agriculture, and a few great staples form the chief reliance of the landholders. It is easy to see that this state of things grows out of the recent secondary, the tertiary, and the alluvial formations, which constitute the ocean-barrier from Staten Island to Florida, and from Florida to Texas, extending inland toward the mountains. In the *West*, the boundless fertile prairies and other tracts of productive soil, conspire, with remoteness from the ocean, to indicate agriculture and pasturage as the main employment of the inhabitants, while exhaustless beds of coal, limestone, plaster of Paris and rich deposites of lead and copper, and salt fountains both numerous and copious, furnish means for a manufacturing, as well as an agricultural population. These pursuits occupy the greater number of the people, while many find a profitable employment in navigating those immense inland seas,—the great lakes, and the vast rivers, which run thousands of miles before they mingle with the ocean.

"What geologist fails to perceive that this state of things is the result of the immense lower secondary and transition formations which cover the Western States, sustaining portions of tertiary, and like all countries, alluvial depositions. While New England produces granite, marble, and other building materials of excellent quality, Pennsylvania, with the Western, and several of the Southern and Southwestern States, supplies inexhaustible magazines of coal, to prompt and sustain the manufacturing interests of this wide country, and to aid its astonishing navigation by steam, already of unexampled extent on its internal waters, and destined at no distant day to compete on the main ocean in amicable rivalry with our parent country."

That the character of a people is influenced by the geological structure of the country, is now a well established truth; and it is equally true that those individuals of a community who earn a livelihood by labor requiring a constant exercise of skill, ingenuity, and judgment, will exhibit far greater powers of reasoning and thought than those who merely follow some routine occupation demanding no exercise of the rational faculties. "Some may contend," says Professor Hitchcock, "that it is more important to transfer the New England character to the unsettled West, thus to multiply our numbers and wealth at home. But the history of the world leads us to fear that the New England character cannot long be preserved except upon New England soil, or upon a soil that requires great industry for its cultivation. Place New England men where the earth yields spontaneously, and the locks of their strength will soon be shorn. If we look over the map of the world and the history of the past, we shall find, as a general fact, that the brightest exhibitions of human character have been made in regions where nature has done less, but art and industry more. If, therefore, we wish to increase the moral power of New England, it must be done by improving her soil, and increasing her resources and population. If these views are correct, which, I acknowledge, do not fall in with the prevailing notions, they furnish a new stimulus for vigorous effort in the improvement of our soils."

Climate is happily defined by Cabanis—"*L'ensemble de toutes les circonstances naturelles et physiques, au milieu desquelles nous vivons dans chaque lieu.*" This correct view of the subject was taken even by Hippocrates, in his treatise entitled "*de aëribus, aquis, et locis.*" The influence of climate on our physical organization, even in many of its detailed effects, was observed by him. To this agency he ascribed, on the one hand, the indolence and effeminacy of the Asiatic, and, on the other, the activity and the courage of the European. He even observed that the inhabitants of mountains in warm climates resemble those of very cold regions: and also that political institutions are much modified by local circumstances. He was aware that cold and temperate climates augment the muscular forces, at the same time that they diminish the power of sensation; and that very hot climates, on the contrary, produce temperaments in which the sensibility predominates over the motive forces. Hence the former induce energy and industry, and the latter, indolence and inactivity. Fertile lands, in which the temperature is mild, exercise a happy and cheerful influence upon the physical, mental, and moral constitution; while a soil of a sterile nature, by requiring a constant exercise of industry, renders a people sober and reflecting. That warm and moist climates induce obesity and laxity of frame, is a fact that was very early observed; so much so, indeed, that the stupidity and sluggishness of the Bœotian, contrasted with the acuteness of the Athenian, grew into a never-dying proverb.

SECTION II.

Mode of classification of the climates of the United States adopted.—Method of making the thermometrical observations.—Description of the general physical features and the natural productions of each State embraced in the Northern Division.—Modifying influence of the Atlantic and especially the Pacific oceans and the great lakes, as evidenced in the difference between the mean temperature of winter and summer, of winter and spring, of the warmest and coldest month, and in the mean annual range of the thermometer.—Extreme range of the mercury in the Northern Division.—These laws confirmed by the reports of the Regents of the University of the State of New York.—Extreme seasons from the earliest period of our colonial history.—The meteorological phenomena of Canada, Nova Scotia, New Brunswick, and Newfoundland, in harmony with the laws of climate developed in the United States.—Winds.—Rain and atmospheric moisture.—Description of the Middle and Southern Divisions, as regards meteorological details and the general physical features and natural productions of each State.

With these preliminary remarks, we are prepared to enter into a detail of the numerical results furnished in the several systems of climate pertaining to the United States. Did the phenomena of temperature, as already remarked, depend solely on the position of the sun, climates might be classified with mathematical precision; but as the effects produced by solar heat are so much modified by local causes that the character of a climate can be determined only by observation, it becomes necessary to adopt a classification of climates based on physical geography, without reference to latitude. The military posts furnishing the thermometrical data, will consequently be classified as under:—

General Divisions of the United States.	*Systems of Climate.*
1. Northern.	1st Class.—Posts on the coast of New England, extending as far south as the harbor of New York.
	2d " Posts on the northern chain of lakes.
	3d " Posts remote from the ocean and inland seas.
2. Middle.	1st Class.—Atlantic coast from Delaware Bay to Savannah.
	2d " Interior stations.
3. Southern.	1st Class.—Posts on the Lower Mississippi
	2d " Posts in the Peninsula of East Florida.

These general divisions, intended as well to facilitate description as to express the operation of general laws, may be regarded, in a great measure, as arbitrary. The *Northern* embraces a region characterized by the predominance of a low temperature; in the *Southern*, a high temperature prevails; while the *Middle* exhibits phenomena vibrating to both extremes. Each of these general divisions, as exhibited in the table above, is subdivided into well-marked classes or systems.

As the plan of the present work will not allow the admission of extensive tables of figures, the author is obliged to confine himself to mere results, referring the reader who may be more curious on this subject, to the author's larger work—"The Climate of the United States and its Endemic Influences"—which contains a series of extensive tabular abstracts of instrumental observations. These results are obtained from observations made at the various military posts between 24° 33′ and 46° 39′ of north latitude, embracing a space of 22° 6′, and an extent of longitude stretching from the Atlantic to the Pacific. The thermometrical observations were made thrice daily; and as the mean of each month is calculated from 90, and of each year from 1,095 observations, the numerical ratios, it is believed, will give an approximation to the truth as near as can be realized by ordinary observation, and a mean sufficiently correct for every contemplated purpose. The results, at the majority of the posts, are based on from five to ten thousand observations.

1. THE NORTHERN DIVISION.—As this region presents the greatest diversity of physical character, so it exhibits the most marked variety of climate. East of the chain of great lakes, there are several mountain ranges, which, with the exception of a few summits, seldom attain a height of more than 2500 feet above the level of the sea; and of this elevation, perhaps one-half is formed by the table-lands upon which the ridges rest. Above the falls of Niagara, the region of the lakes is elevated 600–700 feet above the ocean, but there are scarcely any ridges that deserve the name of mountains. This immense tract is, with the exception of the Eastern States, nearly altogether in a state of nature, being still covered with its dense primeval forests. But the most striking characteristic in the physical geography of this Division, is that produced by its vast lakes or inland seas. We here behold a chain of lakes presenting a superficial area of 94,000 square miles, with a mean depth of 1000 feet in the principal lakes, the details of which have just been given. But as the physical aspect of a country, the nature of the soil, and its vegetable productions, are intimately connected with the character of climate, a more precise description becomes necessary. Let not the reader be surprised at the frequent reference made to physical geography, for these are the great causes which modify climate on the same parallels of latitude. The remark of Malte-Brun, given on a preceding page, is so much to the point, that its repetition here will surely not be regarded as out of place:—"The best observations upon climate often lose half their value for the want of an exact description of the surface of the country."

Maine.—In this State, there is no connected ridge of mountains, but the north-western part contains numerous detached elevations. A characteristic feature is its numerous lakes, it being estimated that one-sixth part of its surface is covered with water. A large portion of the State is yet clothed with the primitive forests, which furnish the most important articles of commerce. The larch, red and white pine, hemlock, white oak, white cedar, spruce, sugar-maple, &c., are found abundantly. Although a great portion of the soil is fertile and well adapted to the culture of wheat, Indian corn, and other grain, yet little attention has been paid to the developing of the agricultural resources of the State. With the exception of the Acadian or French settlement on the St. John's, the whole population is concentrated on a comparatively narrow strip in the southern portion.

New Hampshire.—With the exception of the south-eastern angle of the State, the surface is hilly or mountainous, the elevations rising in height as they recede from the sea, until they finally swell into the lofty grandeur of the White mountains. The great central knot consists of rocky pinnacles shooting up to the altitude of from 5,000 to upward of 6,000 feet. On these summits, the ascent to which discovers several striking changes in vegetation, snow lies during ten months of the year. A large part of the State is yet covered with native forests, which are still haunted, in some places, by the larger kind of wild animals. Of the population, nearly four-fifths live in the southern portion of the State, much of the northern being too rugged and sterile to be susceptible of cultivation. In addition to the forest trees mentioned in the description of Maine, we find the sycamore, ash, oak, locust, hickory, chestnut, etc. The winters are long and rigorous, the prevailing winds being from the north-west. While in winter, the mercury sinks to 15° or 20°, and sometimes 30° and even 40° below zero, in summer it often rises to 96° of Fahrenheit. Toward the end of October, ice begins to form, and snow generally lies till late in April. Cattle are housed from about the first of November till the middle of May, when vegetation is generally sufficiently advanced for them to live abroad.

Vermont.—The most striking natural feature is the range of the Green mountains, traversing the State from north to south. Lake Champlain, covering an area of 500 square miles, and elevated nearly 100 feet above tide-water, lies chiefly within its limits. Originally clothed with a dense forest, a large part of the State still continues in its primeval condition. The mountains produce hemlock, spruce, fir, &c., and the lower ground, the trees found in similar localities in New Hampshire. There is much good arable land, particularly between the mountains and Lake Champlain, but the country in general is better adapted for grazing.

Massachusetts.—Although the face of the country is generally hilly, and in some places rugged, yet it nowhere attains a very great elevation. Of the western sections, some portions are too rough, and of the eastern, some too sandy, for profitable cultivation; but there are both fertile and extensive tracts on the Housatonic, Connecticut, and Merrimack. The fine agricultural district in the central part of the State, contains many flourishing towns.

Rhode Island lies on both sides of Narraganset bay, which covers about one-tenth of its surface. It contains no mountains, but the surface is hilly and rocky, the soil being but moderately productive.

Connecticut.—Mostly hilly or undulating, but never mountainous, much of this State is too rough for cultivation. On all the rivers, however, particularly the Connecticut and Housatonic, there are rich alluvial tracts; and along the shore of Long Island sound, between the mouths of these two rivers, a narrow alluvial flat extends. Rye, maize, hemp, and tobacco, are cultivated.

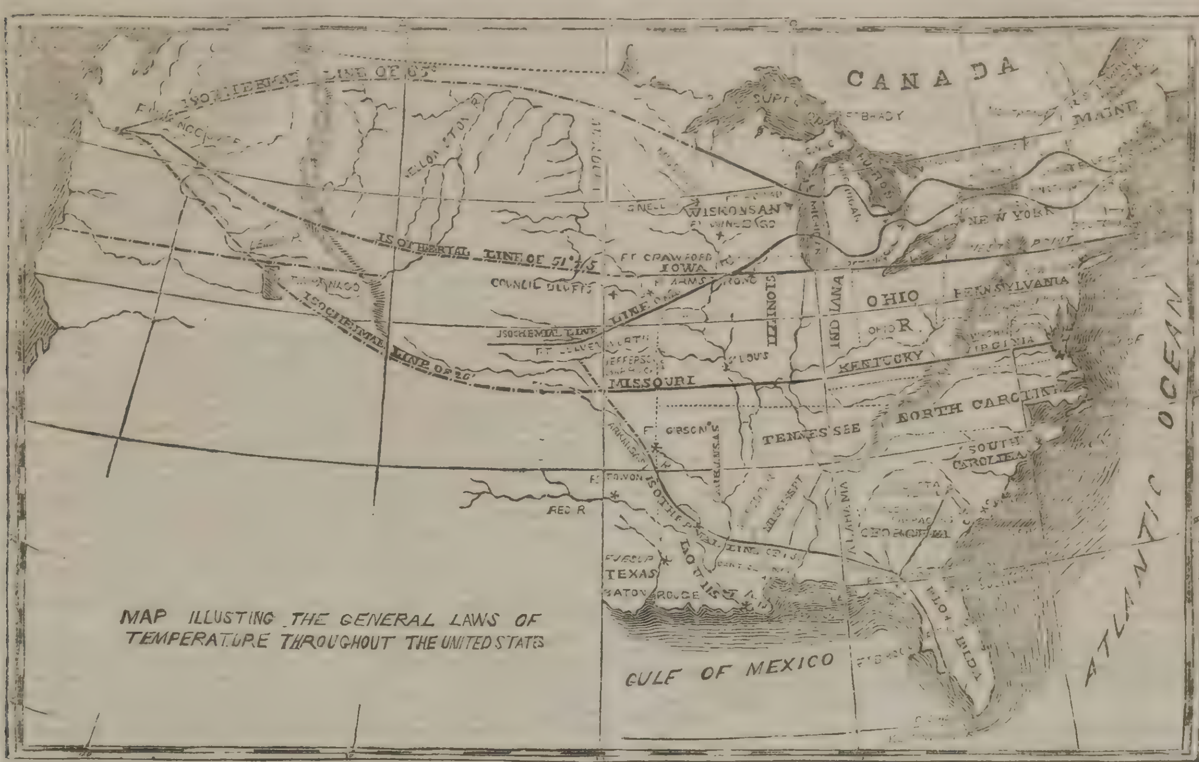
New York.—The surface of this State, for the most part, is considerably elevated, but it is rarely rugged. The greater part lies in fact on the great Alleghany table land. Most of the soil is of a useful quality, and much of it is highly fertile, particularly in the central part of the State, extending from the valley of the Mohawk westward to the great lakes. This is the district of wheat, which is the great agricultural staple.

Michigan.—The *Lower Peninsula* is in general slightly undulating. The ridge dividing the waters flowing into Lakes Huron and Erie from those running into Lake Michigan, rises gradually until it reaches in the north about 300 feet above the surface of these lakes. There are some marshy tracts in the southern part, and some swamps near the margin of the River Detroit and Lake St. Clair. A great portion of the surface is densely covered with oak of several varieties, walnut, hickory, poplar, sugar-maple, etc., intermixed, particularly in the northern part, with white and yellow pine. The forest is interspersed with "oak-openings," plains, and occasionally prairies, which last are not so extensive as those in Illinois. This peninsula, in point of fertility, is not perhaps surpassed by any other tract of equal extent in the world. The alluvial lands in the southern part consist of a rich vegetable mould, from three to six feet in depth. Wheat and Indian corn are chiefly cultivated. The *Upper Peninsula*, which seems to have been very imperfectly examined, appears to be much more hilly and rugged than the *Lower*. It has some lofty ridges, which are said to rise to an elevation of nearly 2000 feet above the level of Lake Superior. Its mineral resources, especially copper, are represented as inexhaustible.

Wiskonsan and Iowa.—This vast tract, exceeding in dimensions, by one-third, the whole kingdom of France, is a part of the great central table-land of North America. It has a general elevation of 800—1200 feet above the level of the ocean, but it does not rise, even on the loftiest summits of its mountain ridges, perhaps more than 2000 feet above the general level. In the northern part, much of the soil is of an inferior quality; but in the southern section, the general features of the country resemble those of the adjoining States. Here are fertile prairies, which, forming wide expanses stretching as far as the eye can reach, are only here and there interrupted by a belt of woodland skirting a river, or by a small grove or clump of trees resting like an island in the midst of the ocean. The whole unwooded tract of the north-western States, constitutes one vast prairie, partially intersected by strips of woodland, forming a striking contrast to the immense forest, which, extending from Hudson's Bay to the Gulf Mexico, and from the Atlantic to beyond the Mississippi, is even now but slightly encroached upon by the labors of man.

As the military posts of the United States are scattered over every portion of this region, the *Northern Division*, we have here extensive data for determining the laws of temperature. In the first place, we have the results of the posts on the coast of New England, from the line of the British Possessions to the harbor of New York; in the second, those of the posts on the great lakes; in the third, those of the posts intermediate to these points and of those beyond the lakes, both alike remote from the ocean and inland seas; and in the fourth place, the results of Fort Vancouver, in Oregon Territory, situated on the Columbia river, about seventy miles, in a direct line, from the Pacific ocean.

In accordance with the diversity in the physical geography, we find that on the sea-coast of New England, the influence of the ocean modifies the range of the thermometer, thus equalizing the temperature of the seasons. Advancing into the interior, the extreme range of the temperature increases, and the seasons are violently contrasted. Having come within the influence of the great lakes, a climate like that of the sea-board is found; and proceeding into the region beyond the modifying agency of these inland seas, an excessive climate is again exhibited. And if we continue our route as far as the Pacific Ocean, a climate even more mild and equable than similar parallels in Western Europe, as will be satisfactorily demonstrated, will be presented. The variations of the *isotheral* and *isochimenal* curves—the lines of equal summer and of equal winter temperature, as illustrated in the map here



presented—thus afford a happy illustration of the equalizing tendency of large bodies of water. Hence the former division of the surface of the earth into five zones, as regards its temperature, has been superseded in scientific inquiries, by a more precise arrangement. Places having the same mean annual temperature are connected by isothermal lines, and the spaces between them are called isothermal zones.

It is thus seen that, notwithstanding the mean annual temperature presents little variation on the same parallels, four striking inflections of the isotheral and isocheimal lines are exhibited in rapid succession, constituting two systems of climate, viz., that of the Atlantic ocean and the great lakes which pertains, comparatively speaking, to the class of *mild* or *uniform*, and that of the intervening tract and the region beyond the lakes, characterised as climates emphatically *excessive* or *rigorous*. The difference of climate, as the mean annual temperature is nearly the same, is, therefore, owing to the unequal distribution of heat among the seasons, as is well illustrated in the above map. At the posts on large bodies of water, the mean temperature of winter is higher and that of summer lower than in the opposite localities; but these results are more satisfactorily evidenced by comparing the difference between the mean temperature of winter and summer, and the warmest and coldest month in each system of climate. Thus Fort Brady, at the outlet of Lake Superior, shows a difference of only 42°.11 between the mean temperature of winter and summer, while Hancock Barracks, half a degree farther south, in the state of Maine, distant only 150 miles from the sea-coast, exhibits a disparity of 46°.19; and comparing the warmest and coldest month, the difference of the former is 47°.22, and that of the latter 51°.70. Again, Forts Sullivan and Snelling, in opposite systems of climate, are very nearly in the same latitude, the former at Eastport, on the coast of Maine, and the latter at the junction of the St. Peter's and Mississippi, Iowa. At Fort Sullivan, the difference of winter and summer is 39°.15, and that of the warmest and coldest month, 43°.87; while at Fort Snelling, these ratios are respectively 56°.60 and 61°.86. Fort Howard is also in the same latitude, but as it is situated at the extreme point of one of the smaller lakes, (Green Bay, Wiskonsan,) the temperature is partially modified, these averages being 50°.05 and 54°.11. Next come four posts, all of which are nearly on the same parallel, three being of the class of *uniform* climates, and one of that of *excessive*. Of the former, two, Forts Preble and Constitution, are on the ocean, and the other, Fort Niagara, is on Lake Ontario. At these posts, in the order just named, the difference between the mean temperature of winter and summer is respectively 41°.03, 36°.33, and 41°.73; while, on the other hand, at the *excessive* post, Fort Crawford, Wiskonsan—a point a few minutes farther south than the three former—the difference is 50°.89. The results at Salem, Massachusetts, based on 33 years' observations by Dr. Holyoke, though not directly under the influence of the ocean, confirms the same law, the difference between the mean temperature of winter and summer being only 41°.66. At all these points, the contrast in the difference of the mean temperature of the warmest and the coldest month, is equally striking. The next points of comparison, as lying on the same parallel, are Forts Wolcott and Trumbull on the Atlantic, and Council Bluffs, Fort Armstrong, and West Point, in the opposite localities. The difference between the mean temperature of summer and winter at Fort Wolcott, Newport, Rhode Island, is 36°.55, and at Fort Trumbull, New London, Connecticut, it is 32°.56; while at Council Bluffs, near the junction of the Platte and Missouri, it is 51°.35—at Fort Armstrong, Illinois, [illegible]°.05—and at West Point, New York, 40°.75. Between the two posts on the ocean and the two far in the interior, the difference between the mean temperature of summer and winter presents a disparity of from 15° to 17°; and as respects Fort Trumbull and West Point, which are precisely on the same latitude, the difference between these two opposite seasons, notwithstanding the latter is not more than fifty miles from the ocean, is 8°.19 less at the former post. As regards the difference between the mean temperature of the warmest and coldest months, these laws find confirmation in every instance. So remarkable is the influence of large bodies of water in modifying the range of the thermometer, that although Fort Brady, at the Sault St. Marie, Michigan, is nearly 7° north of Fort Mifflin, near Philadelphia, and notwithstanding the mean annual temperature is more than 14° less, yet the contrast, in the seasons of winter and summer, is not so great at the former as at the latter. Fort Columbus, in the harbor of New York, offers, in some respects, an exception to the laws just developed, the range of the thermometer being greater than at some points farther north. As these results, which are based on nine years' observations, made on an island free from any agency which large towns may exercise, are, doubtless correct, some causes of a local nature must exist to produce this effect. It is more than probable that this locality, in consequence of the configuration of the coast, does not lie in the direction of the most prevalent ocean-winds, and that hence its temperature is but partially modified.

The climate of Fort Snelling, which is the most excessive among all the military posts in the United States, resembles that of Moscow in Russia, as regards the extremes of the seasons, notwithstanding the latter is 11° farther north; but at Moscow, the mean temperature both of winter and summer is lower—that of winter being as 10°.78 to 15°.95, and that of summer as 67°.10 to 72°.75. At Edinburgh, Scotland, in the same latitude as Moscow, the difference between the mean temperature of winter and summer, is, on the other hand, not one-third as great, being only 17°.90; and even at North Cape, on the island of Maggeroe, in latitude 71,° which is the most northern point of Europe, this difference between the two seasons, so great is the modifying influence of the ocean, is no more than 19°.62, while at Uleo, in the interior of Lapland, the difference between the mean temperature of summer and winter is 45°.90.

In these comparisons of the Northern Division, no particular reference has yet been made to Fort Vancouver, in Oregon Territory. This region bears the same climatic relation to our coast and to that of Eastern Asia, as the western coast of Europe does. The mean annual temperature is about 10° higher than that of the posts on the same parallel on our own coast. So mild and uniform are the seasons at Fort Vancouver, that the difference between the mean temperature of winter and summer is only 23° 67—a mean which is less than that of Italy or Southern France, and only about two-fifths of that of Fort Snelling, Iowa, notwithstanding the latter is nearly 1° farther south. This contrast is well exhibited in the map just given; for whilst the mean temperature of spring, summer, and autumn, at Fort Vancouver, is about the same as at Fort Wolcott, Rhode Island, the winter line comes nearly as far south as Fort Gibson, Arkansas. But even this comparison, at first view, falls short of the reality; for, as regards the difference between the mean temperature of winter and summer, the contrast is less at Fort Vancouver than at Cantonment Clinch near Pensacola, or Petite Coquelle near New Orleans. These results, however extraordinary they may appear, find, as will be seen, an explanation in physical causes.

The next point demanding attention is the difference between the mean temperature of winter and spring, which is much the greater in the *excessive* or rigorous climates. Taking places in the same latitude and in opposite systems of climate, it is found at Fort Brady to be 18° 42, whilst at Hancock Barracks it is 24° 49; at Fort Sullivan it is 17°.16,

whilst at Forts Snelling and Howard, it is respectively 30°.83 and 24° 18, the latter being partially modified by Green Bay; at Forts Preble, Niagara, and Constitution, and the city of Salem, the ratios are 18°.42, 16°.77, 16°.83, and 17°.89, and at Fort Crawford, on the other hand, it is 25°.83; and lastly at Forts Wolcott and Trumbull, it is 14°.71 and 11°.67, whilst at Council Bluffs, Fort Armstrong, and West Point, it is respectively 27°.47, 23°.99, and 18°82. Fort Columbus, as in the preceding comparisons, stands as an exception, its ratio, notwithstanding it is lower than any one in the opposite class, being the highest in its own, with the exception of two posts. This peculiarity in the increase of the temperature of spring, as manifested in the vegetable kingdom, constitutes a feature which strongly characterizes excessive climates; for, as Baron Humboldt remarks, "a summer of uniform heat excites less the force of vegetation, than a great heat preceded by a cold season." Accordingly we find that in these excessive climates, (unlike the uniform ones on the ocean and lakes, in which the air is moist and the changes of the seasons slow aud uncertain,) summer succeeds winter so rapidly that there is scarcely any spring, and vernal vegetation is developed with remarkable suddenness. At Fort Vancouver, the difference between the mean temperature of winter and spring is only 6°.67, which is about one-third of the difference observed at the posts in our *modified* climates on the same parallel, and little more than one-fifth of the difference exhibited in the *excessive* climate of Fort Snelling.

Another feature which characterizes these two systems of climate remains to be considered, viz., the mean annual range of the thermometer. Comparing the posts on the same parallel, the following relations are found:—At Fort Brady, on the one hand, the range is 110°, and at Hancock Barracks, on the other, it is 118°; at Fort Sullivan it is 104°, while at Forts Snelling and Howard, it is 119° and 123°; at Forts Preble, Niagara, and Constitution, it is respectively 99°, 92°, and 97°, while at Fort Crawford, on the same parallel, it is 120°; and lastly at Forts Wolcott and Trumbull, it is 83° and 78°, while at Council Bluffs, Fort Armstrong, and West Point, it is 120°, 106°, and 91°. Fort Columbus, as before, presents an exception. In further elucidation of the law regulating the extremes of temperature, the four following posts, which are all nearly on the same parallel of 41°30′, the first two being on the ocean, and the last two far in the interior, remote from large bodies of water,—may be adduced as striking examples:

	Highest	Lowest	Mean Annual Range
Fort Wolcott, Newport, R. I.,	85	2	83
,, Trumbull, New London, Conn.,	87	9	78
Council Bluffs, near the confluence of Platte and Missouri,	104	—16	120
Fort Armstrong, Rock Island, Ill.,	96	—10	106

These results, it may be necessary to add, exhibit the *average* range of a series of years. The *extreme* range, for example, at Fort Brady, During a period of eleven years, (from 1820 to 1830 inclusive,) is 130°, the mercury sinking in 1826 as low as—37°, and rising in 1830 to 93° Fahr. At Fort Snelling in 1821, the mercury sunk to—32°, and in 1827 rose to 96°, being a range of 128°. At Fort Howard, in 1823, it rose to 100° and sunk to—38°, being a range in the same year of 138°. At Fort Crawford we find the mercury in 1820 noted as high as 99°, and in 1821 as low as—36°, being a range of 135°; at Fort Armstrong, in 1821, as low as—28°, and in 1830 as high as 98°, being a range of 126°; and lastly at Council Bluffs as low, in 1820, as—22°, and in 1822 as high as 108°, being an extreme range of 130°. At the last named post, the thermometer rose every year above 100°. When the Southern Division of the United States comes under investigation, it will be seen that the mercury there seldom rises as high as in our northern regions.

The laws here developed in relation to the systems of climate peculiar to our northern region, are still more fully established in the "Army Meteorological Register." These details are continued separately through five years, each of which confirms the law that the *isotheral* and *isocheimal* lines, on leaving the coast of New England, gradually diverge until they come within the influence of the great lakes, when they again converge; and that, having passed beyond the controlling power of these inland seas, their inflections are once more in opposite directions. Hence it follows that latitude alone constitutes a very uncertain index of the character of climate; for, as has been abundantly demonstrated, although two places may have the same mean annual temperature, and thus be on the same *isothermal* line, yet as the seasons of one may be nearly uniform and those of the other violently contrasted, the climates will be correspondently different. The aggregate results of these annual details in the "Army Meteorological Register," merely confirm the laws already sufficiently demonstrated. Thus on comparing the sea-coast with the interior remote from the agency of inland seas, based on an average of five years and calculated from the data of two posts in each system of climate, the mean latitude of the posts on the ocean being 43° 18′, and that of those in the opposite locality, 43° 10′, the following results are obtained:—While the difference between the mean temperature of summer and winter on the sea-coast is only 38.° 61, it is in the opposite locality as high as 53.° 37; as regards the difference between the mean temperature of winter and spring, the former is only 16.° 84, and the latter as high as 27.° 02; and as respects the difference in the extreme range of the thermometer, the former is 122°, and the latter 134°. A similar comparison between posts on the lakes and those of the same region situated beyond their influence, shows contrasts, making due allowance for difference of mean latitude, the former being 1° 46′ north of the latter, even greater than in the comparison with the Atlantic coast. The difference between the mean temperature of summer and winter on the lakes is 43°, and in the opposite localities 55.° 84. Between the mean temperature of winter and spring, the difference on the lakes is only 19.° 77, while in the positions in the same region beyond their influence, it is 28.° 96. The results may be presented thus in a tabular form:—

Localities	Latitude	Difference between the mean Temp. of	
		Winter and Summer	Winter and Spring
Sea-coast,	43° 18′	38.° 61	16.° 84
Lakes,	46° 27′	43. 00	19. 77
Region beyond the Lakes,	44° 53′	55. 84	28. 96

Hence it is obvious that the phenomena of terrestrial temperature as depending on the position of the sun, are so much influenced by local causes, that a classification of climates, or a system of medical geography, having for their bases mere latitude, is wholly inadmissible. Although there may be little difference in the mean annual temperature on the same parallel, yet the distribution of heat among the seasons may be extraordinarily unequal.

These laws of temperature are confirmed by the results given in the Reports of the Regents of the University of the State of New York, based on observations made at fifty-four different points and on an average of ten years, (from 1826 to 1836.) At Albany, for example, the mean temperature of January is 23°.38, and of August 69°.60; while at Lewiston, between lakes Erie and Ontario, the former is 27°.70 and the latter 64°.46. Thus the difference between the mean temperature of these two months, is at Albany 46°.22, and at Lewiston only 36°.76. The mean annual temperature of the State of New York, on the average above mentioned, is 46°.31.

It is thus seen that the climatic features of the coast of New England and of the region of the great lakes, exhibit a striking resemblance, while those of the third class of the same division are very dissimilar. In the climate of the third class of posts, distinguished by great extremes of temperature, by seasons strongly contrasted, and a corresponding dryness of the atmosphere, (unlike the first two classes in which the air is moist and the changes of the seasons slow and uncertain,) a constant and rapid succession is observed among the seasons. Summer, for example, succeeds winter so rapidly that there is scarcely any spring, the influence of which is surprisingly manifested in the vegetable kingdom. As the summers of the third class are remarkable for extremes of temperature, the mercury often rising in June, July, and August, to 100° Fahr. in the shade, so the winters are equally characterized by extreme severity. From November to May, cold weather prevails, the ground being often covered with snow to the depth of three or four feet, and the general range of the thermometer being from the freezing point to 30° below zero.

The lowest temperature, taking the mean of a month, occurred at Forts Howard and Snelling. At the former, the mean of the month of February, 1829, at 7 o'clock A. M. is —3°.17, and the mean of December, 1822, at Fort Snelling is —3°.61.* This, it is to be observed, is merely the average of the morning observations for the month. Although the extreme severity of the winters at the posts remote from large bodies of water, has been already fully illustrated; yet the following remarks made by Surgeon Beaumont when stationed in 1829 at Fort Crawford, Wiskonsan, which is in the latitude of Fort Wolcott, R. I., may be added in further elucidation: "The month of January was remarkably mild and pleasant, the ground dry and free from snow, and the Mississippi unusually low and unfrozen. February was extremely cold, the weather clear and dry, and the thermometer ranging during the month from the freezing point to 23° below zero. From the 1st to the 16th, the mercury stood every morning, with the exception of three, (the 6th, 7th, and 8th,) between —4° and —23°, and did not rise above 20° above zero during these days. On the 2d, 3d, 4th, 5th, 9th, 10th, 11th, 13th, 14th, and 15th, the mercury at sun-rise stood respectively at 14°, 16°, 4°, 16°, 23°, 18°, 20°, 18°, 10°, 6°, and 4° below zero; and on the 9th and 14th, it continued under —8° during the 24 hours. During the month the prevailing winds were northerly and dry, and the proportion of fair and cloudy weather was—clear twenty-two days, cloudy three, variable one, and snowy two. The mean depth of snow was about six inches. The month of March has been unusually cold and dry, with one or two light falls of snow, which, with the previous coat, has just been dissolved by the warmth of the solar rays without any rain. The ice on the Mississippi, which broke yesterday, [March 30th] is now moving off *en masse*."

On looking back for the period of a century, it is found that in the winter of 1779–80, the temperature at the city of New York was so low that cavalry and artillery were transported over the ice in the harbor to Staten Island. In the interior of the State, the cold was correspondently intense. All streams were so completely locked up that no grain could be ground in the grist-mills, and the inhabitants were obliged to bruise it in mortars; the snow was so deep that no efforts were made for weeks to reclaim the roads; in narrow ravines it became so drifted as to cover the tops of the highest trees; even many habitations were so buried that their inmates were obliged to tunnel their way to the light of heaven; and lastly, for the period of forty days, no water dropped from the eaves of houses. So say not only the chronicles of the day, but witnesses are yet living to testify to these facts. As we are in possession of the precise knowledge derived from instrumental observations, given below, we know that it was, even on our coast, a truly Russian winter; and the imagination is left to figure to itself the condition of things at the present sites of Forts Snelling, Howard, and Crawford. In this winter, as well as 1741, Long Island Sound was frozen over. There were two other periods within the last hundred years when the Hudson was passable on the ice, for several days, between New York and Powles Hook, viz., the winters of 1764–5 and 1820–1. In the latter winter, the mercury on the 25th January sank to 7° below zero, which is 1° lower than it fell on the 15th February, 1817—a point to which, according to the journals of the day, it had not previously sunk since 1765. The mean duration of winter at the city of New York, on an average of ten years, (1830 to 1840,) calculated from the periods in each year when ice was first and last formed, is 164 days, or about 5½ months; and as the earliest formed ice, in the ten years, was on the 14th of October, and the latest on the 15th of May, the extreme continuance of frost is 213 days, or about seven months. In the more excessive climate of the interior of the State of New York, however, as for example, at Albany, no month of the year is exempt from frost. From a table of the dates when the Hudson river opened and closed at Albany, during a period of twenty-three years, (1817 to 1840,) taken from the report of the Regents of the University, it appears that the average number of days that it was closed, is 91, the longest period being 125, (1835–6,) and the shortest, 50 days, (1827–8.) The longest period on record that the Hudson has remained closed, at the city of New York, was in the winter of 1735–6, when it was obstruct-

* It may be well to remark that the sign — means below zero, and the sign + above it.

ed by ice for 125 days—from the 30th of November to the 4th of April.

In the "*History of Epidemic and Pestilential Diseases*," by Noah Webster, published at Hartford, in 1799, there is an historical account of many important meteorological phenomena, from the earliest ages of the world; of which, those pertaining to the United States will be here presented.

The winter of 1607--8 was the severest known for an age both in America and in England. In the winter of 1641--2, "the bay at Boston was frozen so that teams and loads passed to the town from the neighboring islands. The snow was deep, and Chesapeake bay was nearly frozen over. At Boston, the ice extended to sea, as far as the eye could reach." Dr. Webster remarks that it is very common that severe cold is progressive from east to west, happening in Europe one year before it does in America. This occurred in the present instance. "It often happens, however," he says, "that the winter is severe at the same time, in both hemispheres, as in 1607--8, 1683--4, 1762--3, and 1779--80." In the winter of 1696--7, loaded sleds passed from Boston to Nantasket. In 1708--9, the winter was so severe, both in America and in Europe, as to kill vines and fruit-trees. In 1717, there were, says Mr. Winthrop, of New London, "prodigious storms of snow," by which one hundred of his sheep were buried on Fisher's Island; and upon being dug out, twenty-eight days after, two of them were found alive, both of which lived and thrived. The snow was accumulated over them to the height of sixteen feet. This snow-storm is distinguished as by far the greatest ever known in America. The winter of 1740--1 was the severest known since 1709, and it was a year later than an equally remarkable one in Europe. The winters of 1754--5 and 1755-6, on the the other hand, were equally noted for mildness, sloops having sailed from New York to Albany in January and February. In the winter of 1762--3, snow fell on the 8th of November and continued till the 20th of March. The winter of 1766--7 was very severe both in Europe and America, it having commenced one year later in this country. At Brandywine, Delaware, the mercury fell to 20° below zero. It may be here remarked that Webster, in this work, attempts to trace a relation between epidemics and the following phenomena—earthquakes, eruptions of volcanoes, meteors, inundations, and *extraordinary seasons*, all of which he maintains travel from east to west. But "cold and falls of snow," he says, "sometimes run in veins in both hemispheres." Thus in the winter of 1774-5, the rivers of Germany were frozen early in December, and there was a deep snow in Bologna, in Italy, in October, while in England the winter was not severe. A remarkable instance of the same kind occurred in our country in the winter of 1798--9. "The weather," says Dr. W., "was very cold, with immense quantities of snow from the Atlantic to the mountains, but very mild in Canada and the western country, until the close of winter." The winter of 1778--9 was extraordinarily mild. In February, "many people along the river Connecticut ploughed their fields, and in Pennsylvania the peach blossomed."

But the winter of 1779--80 stands forth prominent even in the catalogue of remarkable winters. "From November 25th to the middle of March, the cold was severe and almost uninterrupted." The following was the state of the mercury in January by Fahrenheit's scale, at Hartford, in Connecticut, lat. 41° 44'—

At Sunrise.

January	1	2°	13	8°	25	16° below 0
	2	7° below 0	14	9°	26	6° do.
	3	14°	15	15°	27	2° do.
	4	16°	16	10°	28	8° do.
	5	6°	17	17°	29	20° do.
	6	10°	18	12°	30	15°
	7	9°	19	13° below 0	31	4° below 0
	8	1° below 0	20	5°	1	2°
	9	5°	21	6° below 0	2	3°
	10	19°	22	5°	3	0°
	11	26°	23	9° below 0	4	15°
	12	11°	24	6°	5	8° below 0

The mean temperature in January at sunrise is 4°, being almost 20° lower than the temperature of the same month in ordinary seasons.

"Not only all the rivers, but the harbors and bays in the United States, as far south as Virginia, were fast bound with ice. Loaded sleds passed from Staten Island to New York, [aye, even cavalry and artillery were transported over the ice;] the sound between Long Island and the main land was frozen into a solid highway, where it is several miles in breadth. Chesapeake bay, at Annapolis, where the breadth is five and a half miles, sustained also loaded carriages. The birds that winter in this climate, as robbins and quails, almost all perished; and in the succeeding spring, a few solitary warblers only were heard in our groves. The snow was nearly four feet deep in Atlantic America, for at least three months. The winter was severe in Europe also; and on the 14th of January, the mercury at Glasgow fell to 46° below 0." This last was no doubt a typographical error. If it was 16° below zero, the cold was most extraordinary for that climate. Mercury itself congeals at —39°.

The following summer was very hot. On the 8th July, the thermometer at Hartford, at 11½ A. M., was at 102°, and at 2 P. M., 99½°. In the winter of 1783--4, "the weather was less uniformly cold than in 1780, but the frosts, in some parts of the winter, was most intense. The following was the state of Fahrenheit's thermometer at Hartford—

February	10	19° below 0	14	20° below 0
	11	12° do.	15	12° do.
	12	13° do.	16	16° do.
	13	19° do.	17	16° do.

"The severe cold commenced early; the Delaware at Philadelphia was closed at the beginning of December, and continued bound with ice till the middle of March, notwithstanding a relaxation of cold and a heavy rain in January. The gazettes state that such intense cold has not been known in that city, since 1750--51. The Mississippi was reported to be covered with ice, as far south as New Orleans. At the breaking up of winter, the thaw was sudden, and immense bodies of ice, floating down the rivers, which were greatly swelled, spread ruin along the low-lands on their banks. Great damage was sustained on the banks of the Schuylkill, Susquehannah, Potomac, and James rivers.

In 1784, the summer was extremely hot, the mercury at Hartford being—

June	24th	at 2 P. M.	97°
	25th	" "	96°
	26th	at sunrise	80°
		10 A. M.	96°
		2 P. M.	100°
		3 do.	101°
		4 do.	100°
		sunset,	91°
		10 P. M.	80°
	27th	sunrise,	82°
		7 P. M.	91°

The winter of 1785--6 commenced with a degree of cold rarely known in this country. At Hartford, the mercury stood—

January	17th	at sunrise,	14° below 0
	18th	"	20° do.
	19th	"	24° do.
		at noon	0°
		2 P. M.	3° above 0
	20th	sunrise,	17° below 0

The frost of the whole winter was, however, far less severe than in 1784. In July, 1788, the thermometer rose to 103° in Columbia College, New York, but the general heat of the summer was not excessive. In the winter of 1788--9, the mercury sank to —28°, being 4° lower than it had ever before been observed at Hartford. The season, on the whole, was less severe, however, than in 1779--80 and 1783--4. These researches of Dr. Webster's terminate with the period of the publication of his work, 1799. Since this period, however, we have had seasons of extreme severity. The winter of 1835--6 was perhaps the coldest on record. At Hartford, the temperature during several weeks, it is said, was, a great proportion of the time, down to zero, and several times the mercury was as low as—27° and—28°, and even —30°. At Dover, New Hampshire, it was reported to be as low as —28°, and at Concord —32°, on the 4th of January.

Scarcely does a winter elapse that the Hudson River is not frozen over even in the vicinity of the city of New York; whilst Philadelphia, and even Baltimore, lying on the same parallels which in Europe produce the olive and the orange, have their commerce often interrupted from the same cause. The Delaware, which is the latitude of Madrid and Naples, is generally frozen over five or six weeks each winter. Even the Potomac becomes so much obstructed by ice that all communication with the District of Columbia by this means, is suspended for weeks. Further north, the mouth of the St. Lawrence is shut up by ice during five months of the year; and Hudson's Bay, notwithstanding it is in the same latitude as the Baltic Sea, and of thrice the extent, is so much obstructed by ice, even in the summer months, as to be comparatively of little value as a navigable basin.

We find, however, even on our northern coast, a climate comparatively mild. As Nova Scotia is perfectly insular, with the exception of a neck of land eight miles wide, and is so much intersected by lakes and bays that nearly one-third of the surface is under water, the mercury seldom arises above 88° in summer, or sinks lower than 6° or 8° below zero in winter. In addition to this, some influence must be exercised by the gulf-stream, which strikes upon this part of the coast, "in tides of from 60 to 70 feet, overflows the country to the distance of several miles, and converts the mouths of streams, fordable at low water, into extensive arms of the sea, where whole fleets may ride at anchor."

The meteorological phenomena of Canada, Nova Scotia, New Brunswick, and Newfoundland, according to the data furnished in the British Army statistics, are in perfect harmony with the laws of climate developed in the United States. The climate of Nova Scotia, from the causes just stated, exhibits a marked contrast to that of Lower Canada on the same parallels. In Newfoundland, the climate is similar to that of Nova Scotia; but the summers, in consequence of the melting of the ice-bergs on the coast, are less warm, of shorter duration, and subject to more sudden vicissitudes. In Canada, remote from the Lakes, the climate is of the most excessive character. At Quebec, when walking along the streets, the sleet and snow frequently freeze in striking against the face; and here too the alternations of temperature are so sudden, that the mercury has been known to fall 70° in the course of twelve hours. Cold weather sets in as early as November, from the end of which month till May the ground remains covered with snow, to the depth of three or four feet. When the winds blow with violence from the north-east, the cold becomes so excessively intense, that the mercury congealed in the thermometer serves no longer to indicate the reduction of temperature. Wine and even ardent spirits become congealed into a spongy mass of ice; and as the cold still augments, there follows congelation of the trees, which occasionally burst from this internal expansion, with tremendous noise. During winter, the general range is from the freezing point to 30° below zero. The seasons do not, as in more temperate regions, glide imperceptibly into each other. In June, July, and August, the heat, which often attains 95° of Fahrenheit, is frequently as oppressive as in the West Indies

On our western coast, the extremely modified climate of the region of Oregon, on a parallel five degrees north of the city of New York, has been already illustrated. During a year's observations at Fort Vancouver, the lowest point is 17°, and the whole number of days below the freezing point, are only nine, all of which are noted in January. We are told by Mr. Bell, of the State of New York, by whom these observations were made, that he commenced ploughing in January of the year 1833. "The vegetables of the preceding season," he says, "were still standing in gardens untouched by the frost. New grass had sprung up sufficiently for excellent pasture. * * * Though the latitude is nearly that of Montreal, mowing and curing hay are unnecessary, for cattle graze on fresh-growing grass through the winter. * * * Winters on the Columbia River are remarkably mild, there being no snow, and the river being obstructed by ice but a few days during the first part of January. Grass remained in sufficient perfection to afford good feed; and garden vegetables, such as turnips and carrots, were not destroyed, but no trees blossomed till March, except willow, alders, &c."

Winds.—As our military posts have never been supplied with an

instrument, (*anemometer*,) required for ascertaining correctly the direction of winds, it is not to be expected that these observations are characterized by much precision. As winds are currents of air occasioned by the unequal distribution of heat, it follows that each variety of climate must have a system of winds correspondently modified. Along the course of the great lakes, a strong breeze blows during most of the summer, setting in about 10 A. M., and continuing till 4 P. M. During spring and autumn, the wind generally comes from the same quatrer. In winter, winds from the north, varying from east to west, mostly prevail. It has been observed that the number of days in a year during which the winds blow from a certain point of the compass, at a given place, preserves a pretty constant ratio—a result arising independent of the great atmospheric currents, from the fact that the force and direction of winds depend on causes peculiar to the locality, such as the declination of the sun, the configuration of the coast, the position of neighboring continents, the vicinity of great seas, and, in a word, all those physical causes which influence the laws of temperature. This fact is generally illustrated throughout the United States. By way of example, the results of five posts, selected at random, in different regions of our vast territory, may be presented. At Fort Brady, Michigan, the highest ratios of wind each year are the S. E. and the W., and the lowest ratios the N. and the N. E. At West Point, the highest average each year is given by the S. W. winds, and the lowest by those from the E. At Washington city, the prevailing winds each year are the N. W., and the opposite ratios are the N. and W. At Cantonment Clinch, near Pensacola, the S. W. winds give the highest ratios, and the E. the lowest. Lastly, the annual results at Fort Gibson, Arkansas, invariably show the ratio of the S. E. to be the highest, and the W. the lowest. In regard to the annual proportion of fair and cloudy weather in each of these localities, the results are still more uniform.

In the State of New York, according to the Report of the Regents of the University, the prevailing wind is N. W.—a result based on observations made at fifty-four places, and on an average of ten years. This might have been inferred *a priori* from the general law of heat, by which a current of air is established towards the point where the greatest rarefaction exists. As the regions on the same parallel, remote from large bodies of water, are relatively colder in winter and hotter in summer, the winds will be correspondently various; but as the region lying north-west of the State of New York is the coldest point of the compass, the prevailing winds will necessarily be from that quarter.

Rain and Atmospheric moisture.—It is to be regretted that we do not possess more exact and numerous results in reference to the rain guage; and as few observations have been made upon the hygrometer, the ratios of fair and cloudy weather present the chief means of determining the comparative degree of atmospheric humidity. The results obtained by five years' observations, discover a remarkable contrast between localities on the lakes and those not within their influence. In the former, the prevailing weather is *cloudy*, the relative proportion of rainy and cloudy days, during the year, being 247, and in the latter, *fair*, the annual ratio being only 148. It is evident that the annual quantity of rain that falls upon any point of the earth's surface, depending, as it does, upon the amount of evaporation and the prevailing winds, is very intimately connected with the character of climate. The annual quantity of rain, on an average of three years, is, at Fort Brady, 31.89 inches, and at Fort Snelling, 30.32. Contrasted with the relative number of rainy and cloudy days, the difference in the annual amount of rain is small. But the annualquantity of rain is no index of the humidity of any climate; or if it is, the ratios are in an inverse proportion, as the number of rainy days is generally least where the fall of rain is greatest. As rain in cold or temperate localities on large bodies of water, descends more frequently, but in much slighter showers, than in warm or inland regions, a ready explanation is afforded of the fact that the ratio of wet and foggy days on the great lakes is so much higher than in the climates on the same parallels characterized as rigorous or excessive.

Taking a general view of the results afforded by the twenty-five military posts at which observations on the pluviometer have been made, no corroboration of the general law, that the quantity of rain increases in proportion as we approach the equator, is afforded, inasmuch as the average of Key West is one of the lowest in the table. Among the northern posts, Forts Wood, Hamilton, and West Point, present the highest ratios. But the average of these three posts, (47.44 inches,) is considerably higher than the mean of the State of New York, as given in the Report of the Regents of the University. The general average, from observations made at fifty-four different points, is 34.40 inches, while the highest annual mean is 43.81, and the lowest, taking a point at which the observations have extended to five years, is 27.31 inches. Forts Wood and Hamilton, however, have maritime positions in the harbor of New York; and the high mean of West Point may be referred to the local circumstances of the place; for, among the various causes which influence the fall of rain, the difference between plains and mountainous districts is so great, that at Paris the annual quantity is only twenty inches, while at the great St. Bernard, the highest meterological station in Europe, it is 63 inches. But this subject has been already pretty fully noticed.

In regard to the *hygrometer*, it may be observed that its daily range in the United States is much greater than in Great Britain and the other European countries; but the dew-point in our climate is, as a general rule, many degrees below the temperature of the atmosphere. A general idea of the mean state of the dew-point in the northern Division of the United States, in a locality remote from large bodies of water, is afforded by the following abstract of a register kept by M. H. Webster, in 1836, at Albany, N. Y.:

Jan., 18° 34	April, 31°.46	July, 64°.14	Oct., 35 58
Feb., 12.26	May, 46.49	Aug., 56 67	Nov., 31.20
Mar., 17.23	June, 59.40	Sept , 54 82	Dec., 24 90

These results are the mean of two daily observations, the maximum and minimum. A comparison of these results with those obtained at Schenectady, N. Y., for the corresponding months of the same year, does not, in any instance, reveal a difference exceeding two degrees—a remark that applies equally to the relative state of the dew-point in the city of New York. The mean annual dew-point in the city of Quebec, in 1829, was 39°. 3, which differs but six-tenths of a degree from the result obtained in Albany, in 1836. The dew-point is England, as shown by the results of the observations of the Meteorological Society of London, corresponds during the spring aud summer months very closely with that obtained in New York, Canada, and New England; but during the winter months, the mean hygrometer is considerably higher. For example, the mean at London and Albany respectively was—

	Jan.	Feb.	March.	April.	May.	June.
London	33°.5	35°.0	36°.1	37°.9	45°.3	56°.4
Albany	18°.34	12°.26	17°.23	31°.46	46°.46	57°.40
	July.	Aug.	Sept.	Oct.	Nov.	Dec.
London	58°.6	57°.5	55°.2	47°.7	38° 5	35°.7
Albany	64°.14	56°.67	54°.82	35° 58	31°.20	24°.90

"In high latitudes," says Dr. Charles A. Lee, who has furnished the above facts, "the dew-point and the temperature during the summer months, are often nearly or quite coincident. Thus Captain Parry, on board the Hecla, in 1824, found the dew-point, June 6th, 51°, the temperature 52°; 10th, dew-point 52°, thermometer 52°; July 9th, dew-point 36°, thermometer 36°; 10th, dew-point, 32°, thermometer 34°; 11th, dew-point 33°, thermometer 33°. * * At Columbia College, New York, during the 21st and 22d of June, 1838, Professor Renwick found the range of the hygrometer to be 48°, (from 23° to 71°,) and approaching within 3° of the temperature of the atmosphere. According to the observations of the Meteorological Society of London, the range of the dew-point, during the same time, in that city was but 2°, (the mean hygrometer 58°.52, mean thermometer 59°.64.)"

MIDDLE DIVISION.—This division comprises two general systems of climates, which bear, in some degree, the same meteorological relation to each other as the modified climate of the great lakes and the coast of New England does to that of the third class of the same division. The posts furnishing the meteorological data of the Middle Division are the following:—Fort Mifflin, near Philadelphia, Washington City, Jefferson Barracks, near St. Louis, Fort Monroe or Old Point Comfort, in Virginia, Fort Gibson, in Arkansas, Fort Johnston on the coast of North Carolina, Augusta Arsenal, Georgia, Fort Moultre, Charleston Harbor, and Fort Jesup, near Sabine River, Louisiana. The laws of climate developed in the preceding division, do not find so happy an illustration in this one; for as the physical causes act less prominently, the effects are less marked. These posts cannot be happily arranged into the two classes of uniform and excessive climes, as the majority of them are of a mixed character. Fort Mifflin and Washington City do not properly pertain to either class, being in a measure under the influence of the Atlantic, while the south-western stations experience the powerful agency of the Gulf of Mexico. As we proceed south, the seasons become, as a general rule, more uniform in proportion as the mean annual temperature increases. Although the thermometrical results given at Washington City, fairly place it in the class of excessive climates, yet on following the same parallel westward, a still greater contrast in the seasons are exhibited. Thus the difference between the mean temperature of winter and summer at Jefferson Barracks, notwithstanding it is about half a degree further south than Washington City, is 1°.80 greater; and on comparing Fort Gibson, Arkansas, with Fort Monroe on the coast of Virginia, though the latter is 1°15′ north of the former, the difference at Fort Gibson, in the same respect, is 3°.69 greater. Fort Johnston, on the coast of North Carolina, which is 0° 32′ north of Augusta Arsenal, Georgia, also exhibits a less extreme in the opposite seasons. Fort Mifflin, near Philadelphia, shows a greater contrast in the opposite seasons, (so all-powerful is the equalizing influence of large bodies of water,) than any one of the following posts, all being from two to seven degrees farther north, viz., Brady, Sullivan, Preble, Niagara, West Point, Constitution, Wolcott, and Trumbull; and Washington City exhibits greater extremes than the three last named.

The general laws in reference to the difference between the mean temperature of winter and spring, already revealed in the Northern Division, are here confirmed. Jefferson Barracks shows a greater inequality than Washington City, and Fort Gibson than Fort Monroe. Fort Jesup cannot be fairly compared, by way of contrast, with a position in the same latitude on the Atlantic, as the warm atmospheric currents from the Gulf of Mexico exercise there a very appreciable influence.

The laws developed as respects the mean annual range of the thermometer are also here corroborated. Washington City has a mean annual range of 84°, while that of Jefferson Barracks is 89°; the ratio of Fort Monroe, on the one hand, is 73°, and that of Fort Gibson, on the other, is 89°; and lastly, the range at Fort Johnston is 62°, while that of Augusta Arsenal is 73°.

It is thus seen that the climate of the region of the great lakes on our northern frontier is not more contrasted in the opposite seasons than that of Philadelphia—an inference long since deduced from the fact that similar vegetable productions are found in each, while the same plants will not flourish in the interior of New York, Vermont, and New Hampshire. The region of Pennsylvania, as though it were the battle-ground on which Boreas and Auster struggle for mastery, experiences, indeed, the extremes of heat and cold. But proceeding south along the Atlantic Plain, climate soon undergoes a striking modification, of which the Potomac river forms the line of demarcation. Here the domain of snow terminates. Beyond this point, the sledge is no more seen in the farmer's barn-yard The table-lands of Kentucky and Tennessee, on the other hand, carry, several degrees farther south, a mild and temperate clime.

Conformably to the plan adopted in the Northern Division, the general physical characters of this region will now be brought under notice. Although few thermometrical observations have been made upon the table-land lying in the centre of the Middle Division or upon the ridges which crest this long plateau, thus rendering it impracticable to determine fully the interesting question of their influence upon temperature; yet we are enabled to supply this deficiency, in some measure, by observations made upon the differences in vegetable geography. It may be here remarked that in regard to a classification of soils, the nomenclature commonly received, has been adopted; such as the term, *sandy* or arenaceous, *clayey* or argillaceous, *loam*, which is a medium soil composed of clay and sand, and lastly *vegetable mould*, which contains a large quantity of decomposed vegetable matter.

New Jersey.—The northern portion is traversed by several mountain ranges, which are prolongations of the New York chain. The southern section of the State consists of a low plain, forming the north-eastern

part of the great *Atlantic Plain*, which plays an important part in the production of malarial diseases. It is composed of a series of horizontal deposites of sand, clay, and some limestone, deeply furrowed by the channels of its water-courses, and containing some basins having the character of swamps. The greater part of the Plain is covered with extensive pine-forests, not, however, without many patches of good land.

Pennsylvania.—Stretching quite across the great Apalachian system, it is naturally divided into three strongly marked regions, viz., the Atlantic slope, the Central mountainous region, and the Ohio and Erie table-land. This State, like every other portion of the Union, abounds in noble rivers, and fine rivulets and brooks. East of the mountains, the country is generally under cultivation. Wheat is the great agricultural staple, while the other cereal grains, particularly Indian corn and buckwheat, with flax and hemp, are also extensively cultivated. Of mineral productions, coal, iron, and salt, are the most important in an industrial point of view.

Ohio.—This State consists of a lofty table-land, elevated in the centre about 1000 feet, and on the northern and southern borders from 600 to 800 feet above the level of the sea; but the surface presents no considerable elevation above this general level. The greater part was originally clothed in forests of gigantic trees, upon which only partial inroads have yet been made; but three-fourths of the surface are eminently productive, and nine-tenths susceptible of cultivation, while even the summits of the highest hills have a fertile soil. The river-alluvions, called bottom-lands, are extensive and exuberantly fertile. Prairies and natural meadows are numerous in the centre and north-west of the State. The agricultural productions are those common to the Eastern and Middle States. As in other Western States, Indian corn is a staple, more than 100 bushels being produced from an acre in the rich alluvial soils of the bottom-lands. Wheat, rye, oats, buckwheat, barley, potatoes, and all garden vegetables, thrive luxuriantly.

Indiana.—With the exception of a narrow belt on the southern border, the whole surface is level or slightly undulating. As regards the nature of the soil, in popular acceptation, there are four principal varieties, which characterize all the North-western States, viz., 1. The alluvions of the river-valleys, called bottoms; 2. The forests, consisting of a dense growth of gigantic trees and a thick undergrowth of shrubs and vines; 3. The prairies or unwooded lands, richly covered with grasses and a gay profusion of flowering plants; and 4. The "barrens," or "oak-openings." The prairies, either level or undulating, are more extensive than in Ohio and Michigan, but less so than in Illinois. Grand Prairie on the Wabash is 300 miles long and 100 broad. When broken up by the plough, they soon become covered with trees, being converted into oak-openings. These barrens partake of the character of the forest and prairie, being covered with scattered oaks, interspersed with pine, hickory, and other forest-trees, springing from a rich vegetable mould. The soil is everywhere, even to the summits of the hills, productive, and in general exuberantly fertile. On all the streams are belts of rich alluvial soil of exhaustless fertility. The productive industry is almost exclusively agricultural, such as wheat, Indian corn, hemp, and tobacco.

Illinois.—About two-thirds of the State, the middle and the northern part, consist of prairies, there being no elevation of more than 200 feet above the general level. The heavily wooded tracts are mostly confined to the borders of streams. Indian corn and wheat are the staple products, while the culture of oats, rye, buckwheat, wheat, hemp, flax, cotton, and tobacco, also proves successful.

Kentucky.—This State is traversed in its eastern portion by numerous low mountain ridges. Proceeding westward, these bold features gradually disappear, being finally merged into an almost complete level on the Cumberland, Tennessee, and Mississippi. In its primitive state, nearly the whole surface was densely wooded with a forest of majestic trees and a thick undergrowth of gigantic reeds, called cane-brakes; but in the southern part is an extensive tract thinly wooded, with high grass growing amid the scattered and stunted oaks. In point of fertility of soil, much of this State is unsurpassed. Indian corn, wheat, hemp, and tobacco, are the great staples, cotton being but little cultivated.

Tennessee.—The eastern part is mountainous, some ridges rising 3000 feet above their bases, which are elevated about 2000 feet above the sea. In Middle Tennessee, the surface is moderately hilly; and the west beyond the River Tennessee, presents a level or slightly undulating plain. Of this State, a large proportion is fertile and much is eminently productive. Cotton and Indian corn are the staples, but hemp, wheat, and tobacco, are considerably cultivated. Although cotton thrives well in the southern and western portions, yet the climate is not so well adapted to its cultivation as that of the States south of the 35th parallel.

Missouri.—North of the River Missouri, the surface is generally moderately undulating; and, with the exception of the margins of streams, nine-tenths of it is destitute of trees. The alluvial patches along the course of streams are of remarkable fertility, and the soil of the upland is correspondently rich. South of the Missouri and west of the Osage, the country is of the same character; but the region south-east of the latter river is very rugged, being traversed by numerous ridges of the Ozark Mountains. Cotton is raised in the southern part of the State, but tobacco, hemp, wheat, Indian corn, and other cereals, are cultivated with more success.

Arkansas.—The eastern border of the State to the distance of from 30 to 50 miles from the Mississippi, consists of low grounds, interspersed with numerous lakes and swamps, and annually overflowed, with little exception, by the inundations of the Mississippi, Arkansas, and other streams. The surface of this swamp presents in ordinary times a succession of lakes, bayous, cypress-lands, and marshy ground. The ponds, whose depth does not ordinarily exceed three or four feet, are mostly filled with very large cypress trees growing in the water. The marshy ground is covered with trees of immense size, principally gum and sycamore in the lower places, and in the higher and more dry, white oak and hickory, and occasionally dense cane-brakes rising to the height of thirty feet. The valleys are often inundated to the depth of from fifteen to twenty-five feet.

Delaware.—With the exception of the northern part, which, pertaining to the primary formations, is somewhat hilly and rugged, this State lies wholly on the Atlantic Plain. As the States belted by this Plain possess many features in common, they have been reserved for the last in description. In this State there are numerous swamps on the sandy ridge or rather table-land, which, elevated about seventy feet above tide-water, divides the rivers flowing into the Delaware and Chesapeake. Along the Delaware and Atlantic, the shore is flat and in some places marshy. The soil, which is generally light and sandy, is occasionally rendered productive by the river-deposits. The agricultural staples, are wheat and Indian corn. These river-deposites, consisting of a black mud, composed chiefly of vegetable fibre, sometimes attain a depth of fifty feet. As the lowlands are very flat with an argillaceous substratum impervious to water, the ponds which originate from rains and springs, as they become dammed up by fallen trees, leaves, and brushwood, naturally expand into broad basins, termed marshes. These are covered with a black vegetable mould from one to six feet in depth, in which the proportion of organic matter is so great that the soil, if accidentally ignited during a dry season, will continue to burn until extinguished by rain. These phenomena, observed in this State, are no doubt common to the entire Atlantic Plain, or rather augment with the decrease of latitude.

Maryland.—The eastern portion on both sides of the Chesapeake, belongs to the great Atlantic Plain. At the falls in the Susquehannah above Port Deposit, and in the Potomac above Georgetown, we meet the first well defined ridge, which, separating the low lands from the Atlantic slope, may be regarded as a step to a higher plain. Indian corn, wheat, and tobacco, are the agricultural staples. In the southern countries, the culture of rice, cotton, and the palma Christi or castor-oil bean succeeds.

Virginia.—As this state extends quite across the great Apalachian chains, four natural divisions are presented, viz: 1. The tide-water region below the falls of the rivers; 2. The middle region, between the falls and the Blue Ridge; 3. The Great Valley, between the Blue Ridge and the Alleghany Mountains; 4. The Trans-Alleghany regions, west of that chain. The western limit of the first would be marked by a line drawn from Georgetown through Fredericksburg, Richmond, and Petersburg—a low plain, exhibiting no considerable elevations, but deep ravines scooped out by the action of running waters, through which flow broad and sluggish streams. The primary ridge over which the rivers descend into the low country, is about 150 feet high; and here the surface becomes hilly, and proceeding westward, gradually mountainous. The agricultural staples are Indian corn, wheat, rye, oats, and tobacco; but as there is considerable diversity of climate on the same parallel, the phenomena of vegetation are correspondently modified. On the Atlantic Plain, tobacco is the principal staple; in the Great Valley, it is cultivated only in the southern portion; and beyond the Alleghany, its culture is unknown. In the first only is cotton cultivated, and in the southern part quite extensively.

North Carolina.—In this state, the Atlantic Plain, extending sixty or seventy miles from the sea, forms, as it were, a chaos of land and water, consisting of vast swamps traversed by sluggish streams, expanding ever and anon into broad basins. These swamps, which form so striking a feature of this plain, are estimated to occupy 3,000,000 acres; but a great proportion is susceptible of being reclaimed by embankments, and fitted for the culture of maize, rice, cotton, and tobacco. The middle region, corresponding to that described in Virginia, gradually merges into the mountainous country farther west. Here the table-land has an elevation of 1000 or 1,200 feet above the sea, upon which rise many crests, one of which, Black Mountain, has an elevation of 6,426 feet—the highest known summit on this side of the Rocky Mountains. Here, too, as in Virginia, are found great diversity of climate and corresponding difference in the vegetable kingdom. While the low lands yield cotton, rice, and indigo, the western high country produces wheat, hemp, tobacco, and Indian corn.

As illustrative of the comparative temperature of the Atlantic Plain and the adjacent mountain region, the following thermometrical results, noted during the summer of 1839 and 1840 at Flat Rock, Buncombe County, North Carolina, being distant about 250 miles from the Atlantic and having an elevation of perhaps 2,500 feet above the ocean, a e presented:

Places of Observation.	Lat.	MEAN TEMPERATURE.			
		July	August	September	October
Fort Monroe, Coast of Va.,	37° 00′	80°	70°	72°	64°
Flat Rock, Buncombe, N.C.	35° 30′	69°	70°	62°	61°
Charleston, S. Carolina,	32° 45′	81°	81°	77°	71°

The observations made at Charleston embrace the same years as those at Flat Rock, but the results at Fort Monroe comprise the years 1828, '29, and '30. It is thus seen that the difference of mean temperature at Flat Rock and the other two points, taking an average of the latter, is in July 11°, August 10°, September 13°, and October 6°. As regards the monthly range of the thermometer, little difference is presented. As we here discover a difference of temperature equivalent to six or eight degrees of latitude, it is easy to explain the change of climate with its consequent modifications of animal and vegetable life.

South Carolina is also divided into three strongly marked regions—the Low, the Middle, and the Upper country. The first two lie on the great Atlantic Plain. The *Low* country, which extends about eighty miles from the sea, rising imperceptibly to the height of nearly two hundred feet, is covered with an almost unbroken forest of pines, known under the name of "pine-barrens." These barrens are occasionally intersected by fertile veins of land upon a clayey or marly foundation, bearing oak of different varieties, hickory, walnut, maple, etc. But this plain is also dotted with numerous swamps and savannahs. The *Middle* country, which is from thirty to forty miles wide, consists chiefly of sand-hills, interspersed with swamps and valleys producing shrubs and trees indicative of a more generous soil. Beyond the limit of the Atlantic Plain at the lower falls of the rivers, at Hamburg, Columbia, and Camden, the surface is diversified with hill and dale, irrigated by clear, rapid, and pleasant streams, and clothed in forests of oak, ash, beech, walnut, chesnut, hickory, etc., until, in the extreme west, the mountain-crests rise up from an elevated table-land to the altitude of nearly 5,000 feet. The staples are cotton and rice. The Upper country yields the finest wheat, Indian corn, tobacco, etc., whilst the cultivation of rice is confined to the lowlands.

Georgia.—Like the Carolinas, this State is divided into three well-defined belts, extending across the State from east to west. The Atlantic Plain, the northern boundary of which passes near Augusta, Milledge-

ville, Macon, and Columbus, exhibits the usual features; whilst a zone of sand-hills forms a higher terrace, reaching to the base of the mountains and constituting the Atlantic Slope. Extending thence to the sources of the rivers is the hilly region, which, blessed with a mild climate and productive soil, contrasts strongly with the hot, sultry, and malarial region below. Cotton and rice are the great agricultural staples. Some tobacco is cultivated in the middle and northern, and some sugar in the southern parts.

Alabama.—In this State, the Atlantic Plain, which continues in a north-west direction, the northern limit passing near Wetumpka and Tuscaloosa, is little elevated above the Gulf of Mexico, being furrowed with deep ravines, in which the sluggish streams wind their devious course. Much of the soil is sandy and unproductive; but the margins of rivers are amazingly fertile, covered in some places, in a state of nature, with a dense and impenetrable growth of gigantic canes, which often attain a height of more than thirty feet, and in other places clad in forests of oak, hickory, dog-wood, magnolia, etc. North of this great plain, the surface, as in Georgia, becomes hilly and finally mountainous. Cotton absorbs nearly all the attention of the agriculturist. Some sugar is cultivated in the southern, and some tobacco in the northern part. Indian corn is the principal grain-crop; but the culture of indigo, formerly much attended to, is now abandoned.

Mississippi.—The geographical description of Alabama is applicable to this State, only the mountainous region, owing to the north-west direction of the continuation of the Atlantic Plain, is less extensive. Much of the State presents an undulating surface, arising more from depressions below than elevations above the general level. The western border skirting the Mississippi, consists mostly of swamps, marshes, and lagoons; and between Memphis and Vicksburg, the broad and extensive low grounds are subject to frequent inundations, to the distance of ten, twenty, and even thirty miles from the Mississippi. This extensive tract, called the Mississippi or Yazoo Swamps, as umes, during the prevalence of high floods, the character of a marine forest more than that of a woodland bottom. The soil of the State presents three well-defined varieties: First, the bluffs adjacent to the Mississippi overflow; second, the alluvial margins of the rivers; and third, the pine-forest lands. The first, the bluff-zone of Mississippi, which commences as low down as Iberville, Louisiana, and stretches into Tennessee, varying in breadth from ten to forty miles, affords a tract not exceeded in intrinsic value in any other portion of the United States. Tobacco and indigo were the earlier staples, but cotton is now the main object of agriculture. The sugar-cane is cultivated to some extent, and for home consumption, some wheat and Indian corn.

The hot and sultry atmosphere of these low-lands, comprising the whole extent of the Atlantic Plain, in which malarial diseases in every form are dominant, contrasts strongly with the mild and salubrious climate of the mountain regions. In the cooler and less humid atmosphere of the latter, muscular frames and plethoric habits of body predominate,—phenomena which plainly point for an explanation, (when we consider that an atmosphere with a high dew-point rapidly carries off the positive electrity of the earth to the clouds,) to an accumulation of this vital stimulus in the human organization.

3. THE SOUTHERN DIVISION, which is characterized by the predominance of high temperature remains to be considered. On approaching our southern coast, climate undergoes a most remarkable modification. The seasons glide imperceptibly into each other, exhibiting no great extremes. This is strikingly illustrated on comparing the difference between the mean temperature of summer and winter at Fort Snelling, Iowa, and at Key West, at the southern point of Florida, the former being 56°.60, and the latter only 11°.34. Compared with the other regions of the United States, the Peninsula of Florida has a climate wholly peculiar. The lime, the orange, and the fig, find there a genial temperature; the course of vegetable life is unceasing; culinary vegetables are cultivated, and wild flowers spring up and flourish in the month of January; and so little is the temperature of the lakes and rivers diminished during the winter months, that one may almost at any time bathe in their waters. The climate is so exceedingly mild and uniform, that besides the vegetable productions of the southern States generally, many of a tropical character are produced. The palmetto or cabbage palm, the live-oak, the deciduous cypress, and some varieties of the pine, are common farther north; but the lignumvitæ, mahogany, logwood, mangrove, cocoa-nut, etc., are found only in the southern portion of the peninsula. Here also, in common with our southern borders, the fig, date, orange, lemon, citron, pomegranate, banana, olive, tamarind, papaw, guava, as well as cotton, rice, sugar-cane, indigo, tobocco, maize, etc., find a genial climate. In contemplating the scenery of East Florida in the month of January, the northern man is apt to forget that it is a winter landscape. To him all nature is changed; even the birds of the air—the pelican and flamingo—indicate to him a climate entirely new. The author being attached in January, 1838, to a boat expedition, the double object of which was to operate against the Seminoles and to explore the sources of the St. John's, found, in the midst of winter, the high cane-grass, which covers its banks, intertwined with a variety of blooming morning-glory, (convulvulus.) The thermometer at mid-day in the shade, stood at 84° Fahr., and in the sun rose to 100°; and at night we pitched no tents, but lay beneath the canopy of Heaven, with a screen perhaps over the face as a protection against the heavy dews. Notwithstanding the day attains such a high temperature, the mercury just before day-light often sinks to 45°, causing a very uncomfortable sensation of cold. Along the south-eastern coast, at Key Biscayno, for example, frost is never known, nor is ever so cold as to require the use of fire. In this system of climate, the rigors of winter are unknown, and smiling verdure never ceases to reign.

In following out the three divisions of Northern, Middle, and Southern, the lower half of Georgia, Alabama, and Mississippi, would naturally fall within the limits of the last named; and hence the Southern Division was unavoidably encroached upon, in the description of the physical characters of the Middle Division.

Florida.—Belonging entirely to the Atlantic Plain, no part of the surface rises more than 200 feet above the level of the ocean. South of latitude 25°, it consists chiefly of a vast morass, called the *Everglades*. North of this point to the Georgia line, the surface is mostly a dead level, with scarcely an undulation. The ridge dividing the waters east and west, is not more than about 150 feet high, and disappears at Lake Tohopkalika. This northern portion is an extensive pine forest, interspersed with ponds, swamps, low savannahs, and hummocks,* which last are rich bottoms overgrown with trees and a redundant underwood. The soil consists mostly of sand; but the hummocks, which are numerous, have a fertile soil composed of clay and sand. The savannahs which are covered with a tall grass, are inundated during the wet season. The river-swamps are wooded with a variety of heavy trees, while the pine-barren swamps are mostly overgrown with cypress and cypress knees. The nature of the rock formation—a kind of stratified rotten limestone—explains the phenomenon of the frequent bursting forth of full-grown rivers from the surface. But this subject has already been brought under notice in a preceding chapter.

Louisiana belongs nearly altogether to the low-lands, the surface presenting numerous depressions with some hilly ranges in the north-western part. Below latitude 31°, the greater portion of the surface, with the exception of the tract lying between the Pearl and the Mississippi and north of the lakes, is not elevated ten feet above the level of the Gulph of Mexico, and is mostly inundated by the annual floods of the Mississippi or the spring-tides of the Gulf. The Delta of the Mississippi—a name to which its configuration gives it no pretensions—is an alluvial plain covering an area of 12,000 square miles, having an extreme lengths of 230 miles and an extreme breadth of 140 miles. North of latitude 31°, and nearly separated from the Delta by the approach of the Uplands, is another alluvial plain, with a breadth of about thirty miles and a length within Louisiana of 120 miles. The sea-marsh extends westward to the Sabine, varying in breadth from fifteen to forty miles, being nearly on a level with the waters of the Gulf. In the prairies or unwooded plains, which lie between the Teche and the Sabine, the water-courses are skirted with trees, and here and there appear clumps of trees, called, from their isolated appearance in these grassy expanses, *islands*. The agricultural staples are cotton and sugar. Rice, maize, tobacco, and indigo, also thrive well. The climate, according to Darby, is favorable to the peach and fig-tree, but the apple does not succeed well, and the cherry is wholly unproductive.

The climate of Pensacola and of New Orleans, the former represented by Cantonment Clinch and the latter by Petite Coquille, the two posts being respectively in the vicinity of these cities, is nearly as much modified, (in consequence of the agency of the Gulf of Mexico, and in regard to New Orleans the additional influence of large lakes,) as similar parallels in East Florida. The laws of temperature relative to East Florida have been perhaps more satisfactorily determined than in any other region of the United States. We have here the data of four posts fortunately situated, viz., Fort Marion at St. Augustine, on the eastern coast,—Fort Brooke at the head of Tampa Bay,* about thirty miles from the Gulf of Mexico,—Fort King, intermediate to these two points, —and Key West, belonging to the Archipelago, about sixty miles south-west of Cape Sable. As Fort King is situated in the interior, and the other three posts are on the coast, we have an additional illustration, even in a climate characterized by very little distinction of the seasons, of the modifying agency of large bodies of water; for the mean temperature of winter at Fort King is lower, and that of summer higher, than at the other three posts. Although Key West, which is 4° 39' south of Fort King, has a mean annual temperature 3.° 43 higher, yet the mean summer temperature is 2.° 81 lower—a law which is strikingly illustrated on the map of the United States, which shows that the isotheral line of Key West cuts Savannah, Augusta, and Fort Gibson. This equalizing influence of the ocean is still further exhibited in the annual range of the thermometer, the mean of the monthly ranges, and the average difference of the successive months.† During the summer months, the morning and evening observations at Fort King and Key West are nearly the same, the disparity being caused by the exalted temperature of the former at mid-day. As is usual in southern latitudes, there is little variation presented at Key West in the mean temperature of the same month in different years. Within the period of six years, (from 1830 to 1835 inclusive,) the mercury at Key West was never known to rise higher than 90°, or sink lower than 44°.

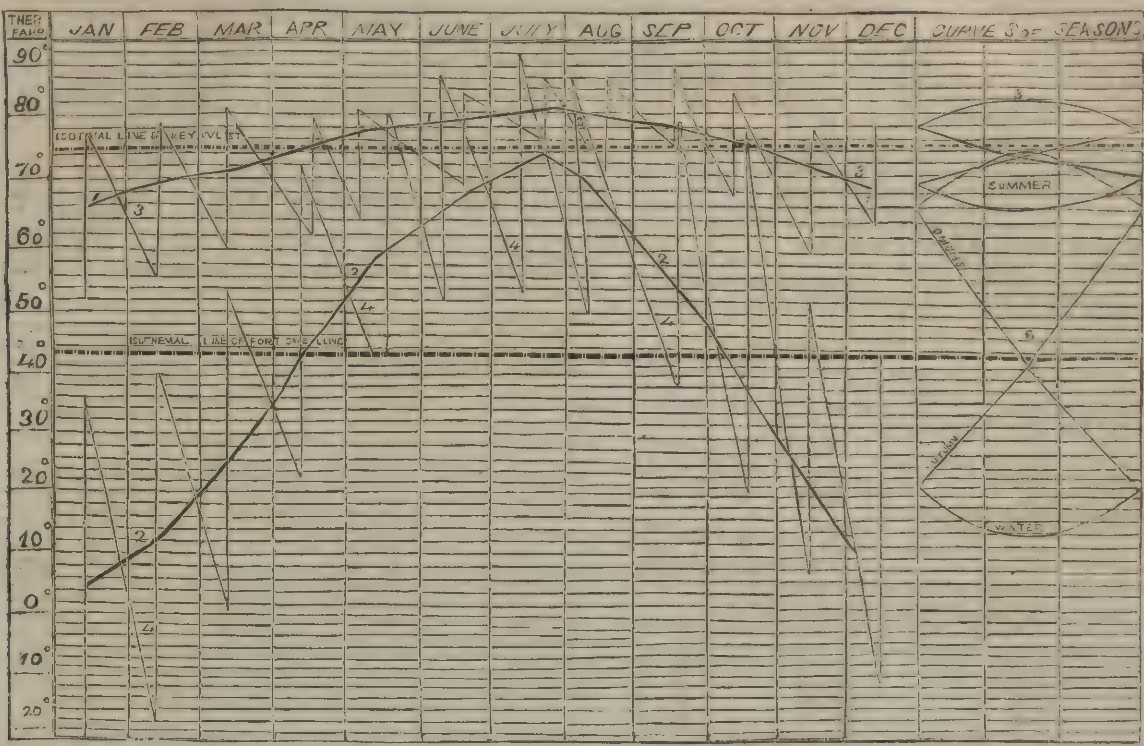
There is little difference between the thermometrical phenomena presented at Key West and the Havana. In the West India Islands, the mean annual temperature near the sea is only about 80°. At Barbadoes, the mean temperature of the seasons is as follows:—Winter 76°, spring 79°, summer 81°, and autumn 80°. The temperature is remarkably uniform; for the mean annual range of the thermometer, even in the most excessive of the islands, is, according to the British army statistics, only 13°, and in some not more than 4°. Contrast this with Hancock barracks, Maine, which gives an average annual range of 118°, Fort Snelling, Iowa, 119°, and Fort Howard, Wiskonsin, 123!

The peculiar character of the climate of East Florida, as distinguished from that of our more northern latitudes, consists less in the mean annual temperature than in the manner of its distribution among the seasons. At Fort Snelling, for example, the mean temperature of winter is 15°.95, and of summer 72°.75, whilst at Fort Brooke, Tampa Bay, the former is 64°.76, and the latter 81°.25, and at Key West 70°. 05, and 81°.39. Thus, though the winter at Fort Snelling is 54°.10 colder than at Key West, yet the mean temperature of summer at the latter is only 8°.64 higher. In like manner, although the mean annual temperature of Petite Coquille, Louisiana, is 2° lower—that of Augusta Arsenal, Georgia, nearly 8°—and that of Fort Gibson, Arkansas, upward of 10° lower,—than that of Fort Brooke; yet at all, the mean summer temperature is higher. Between Fort Snelling, on the one hand, and Fort Brooke and Key West on the other, the relative distribution of temperature stands thus: Difference between the mean temperature of summer and winter at the former 56°.60, and at the two latter 16°.49 and 11°.34; difference between the mean temperature of the warmest and coldest month, 61°.86 compared with 18°.66 and 14°. 66; difference between the mean temperature of winter and spring, 30°.

* The orthography of this word, according to Webster, is *hommoc*. He supposes it to be an Indian word. In Florida, it is now generally pronounced *hammock*.

* The old Spanish appellation was Espiritu Santo, or bay of the Holy Ghost, the name Tampa being then restricted to an arm.

† All these various results are presented in a tabular form in the author's work on "The Climate of the United States and its Endemic Influences."



MAP, EXHIBITING THE DIFFERENT LAWS OF TEMPERATURE AT KEY WEST AND FORT SNELLING.

83 to 8°.35 and 5°.99; and the mean difference of successive months, 10°.29 to 3°.09 and 2°.44.

The diverse climatic peculiarities of Fort Snelling and Key West are delineated in the accompanying engraving. The contrast in the course of the mean annual temperature of these two posts, as traced through each month, is, indeed, striking, while the variation of temperature on each of these monthly lines, is still more marked. Although the average minimum temperature of Fort Snelling in Jannary is as low as 22° below zero, while that of Key West is 57° above; yet, strange to say, we find the mean maximum temperature of July at the former 5° higher than at the latter. The course of the seasons are equally marked in their contrasts; for while those of Key West are confined within a few degrees, those of Fort Snelling are so opposite that spring and autumn traverse each other at right angles, and summer and winter are so remote that the one is truly hyperborean, and the other tropical.

This remarkable equality in the distribution of temperature among the seasons in Florida, compared with the other regions of the United States, constitutes its chief climatic peculiarity; and the comparison, if extended to the most favored situations on the continent of Europe, and the various islands of the Mediterranean and Atlantic held in highest estimation for mildness and equability of climate is no way disparaging. A comparison of the mean temperature, that of the warmest and coldest month, and that of successive months and seasons, results generally in favor of peninsular Florida. The mean difference of successive months stands thus: Pisa 5°.75 Naples 5°.08, Nice 4°.74, Rome 4°.39, Fort King, interior of Florida, 4°.28, Fort Marion, at St. Augustine, 3°.68, Fort Brooke, on the western side of Florida, 3°.09 Penzance, England, 3°.05, Key West, near the southern point of Florida, 2°.44, and Madeira 2°.41. The mean annual range thus: Fort King 78°, Naples 64°, Rome 62°, Nice 60°, Montpelier 59°, Fort Brooke 57°, St. Augustine 53°, Penzance 49°, Key West 37°, and Madeira 23°.

The want of instrumental observations to indicate with precision the actual or comparative humidity of the atmosphere in Florida, is to be regretted. That the air is much more humid than in our more northern regions is sufficiently cognizable to the senses. The deposition of dew, even in the winter, is generally very great. To guard against the oxidation of metals, as for instance surgical instruments, is a matter of extreme difficulty. During the summer, books become covered with mould, and keys rust in one's pocket. *Fungi* flourish luxuriantly. The author has known a substance of this kind to spring up in one night, and so incorporate itself with the tissue of a woollen garment as to render separation impracticable. As the rains, however, generally fall at a particular season, the atmosphere in winter is comparatively dry and serene. The following abstract of the monthly fall of rain at Key West, is the mean of five years' observations:

Jan.	Feb.	Mar.	Ap'l	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual average.
1.82	1.34	1.98	1.09	6.34	2.39	2.84	3.30	4.35	3.33	1.49	1.13	31.40

During six months, from November to May, it will be observed that the proportion of rain is but 8.84 inches, being little above one-fourth of the annual quantity. Now as in tropical climates, a portion of the year is known as the rainy season, and as the same quantity of rain descends in a considerably shorter space of time than in the temperate zone, it follows that the proportion of fair days and clear skies is infinitely in favor of the former. This is strikingly evidenced in a comparison of Fort King, in the interior of East Florida, and of our northern lakes already adverted to, the annual number of fair days at the former being 309, and at the latter only 117. On the coast of Florida, however, the average is not more than 250 days.

In this climate, other meteorical phenomena are similarly modified, but upon these points no precise observations have been made. Thus in countries and seasons in which solar action is most intense, electrical phenomena are most frequent and energetic; and whilst atmospheric moisture favors the passage of electricity from the earth to the clouds, the opposite condition causes its accumulation in objects on its surface. Consequently, in the excessive climates of the Northern Division, thunder and lightning are of rare occurrence, and terrestrial objects are charged with an unusual portion of electricity; whereas in the warm and moist atmosphere of the alluvial zone which skirts our southern coast, opposite phenomena are witnessed. In warm countries, likewise, the influence of the solar beams, and consequently of light, is very influential in modifiying directly the animal and vegetable creation, as well as many of the physical phenomena which make up the character of climate.

Thus it is demonstrated that invalids requiring a mild winter residence, have gone to foreign lands in search of what might have been found at home, viz., *an ever green land in which wild flowers never cease to unfold their petals.* But to treat of the advantages of peninsular Florida as a *winter* residence for pulmonic and other invalids from more northern latitudes, would require a space not here admissible.

SECTION III.

THE same isothermal line presents on the east side of both continents, concave, and on the west side, convex summits.—Difference between the mean temperature of the west of Europe and eastern coast of America on the same parallels.—Comparative difference of the seasons from the equator to the polar circle, between Europe and America.—The rationale of all these laws explained by reference to the polar and equatorial currents, in connection with certain local causes.—The climate of Eastern North America, so far from being an exception to the general rule, demonstrates the harmony of the laws of climate throughout the globe.—The western coasts of Europe and America resemble each other in climate only to a certain point.—The question, whether the old continent is warmer than the new, shown to involve an absurdity.—The general law that the contrast in the seasons from Florida to Canada increases in proportion as the mean annual temperature decreases, is subject to modification on every parallel in accordance with difference in physical geography.—These laws compared with those determined in Europe by Humboldt.—The law that the same causes which produce the greatest convexity of the isothermal line, also equalize the temperature of the seasons, not confirmed in the Northern Division of the United States.—Explanation of the fact why the elevation of our north-western country, 800-1000 feet above the level of the ocean, causes no perceptible diminution of temperature.—Laws in reference to the geographical distribution of plants and animals.—The influence of the unequal distribution of heat upon vegetable geography on the same parallels in the United States, demonstrated, and a comparison made with the laws determined in Europe.—The extremes of heat and cold do not occur at our most northern and southern posts.—Influence of an atmosphere with a high dew point upon the mental and corporeal functions.—The law that the highest temperature in northern latitudes occurs in June, and as we approach the equator in July and August, explained by the laws which regulate the earth's motion.—The same law does not obtain at sea.—The freezing of water and the melting of ice form a beautiful provision of Nature for mitigating the excessive inequality of temperature.—The mooted point whether April or October expresses a nearer equivalent to the mean annual temperature, satisfactorily settled.—Thermometrical observations made by the author at the depth of thirty inches beneath the surface of the earth.—Climate as influenced by clouds, by snow lying on the earth, by the nature of soil, by currents in the ocean and in the atmosphere, and by general and local aspects.—Description of the influence of elevation on vegetable life.—Meridians and poles of greatest cold.

Having completed the details in reference to each division of the United States, the consideration of questions of a more general character will now engage attention.

In the first place, it will be well to take a glance at the general laws of climate, as illustrative of their harmony throughout the globe. It is an important general law in reference to both continents that a striking analogy exists, on the one hand, in the climatic features of the western coasts, and, on the other hand, in those of the eastern shores.

Thus in tracing the same isothermal line around the northern hemisphere beyond the tropic, it presents on the east side of both continents, *concave*, and on the west side, *convex* summits. Following the mean annual temperature of 55°.40 Fahr. around the whole globe, we find it passes on the—

E. coast of Old World, in N. Lat 39°54′, E. Long. 116°27′, near Pekin,
E. coast of New World, " " 39°56′, W. " 76°16′, Philadelphia,
W. coast of Old World, " " 45°46′, " " 0°37′, near Bordeax
W. coast of New World " " 41°40′ " " 104°0′, Cape Foulweather, south of the mouth of Columbia.

On comparing the two systems, the concave and convex summits of the same isothermal line, "we find," says Humboldt, "at New York the summer of Rome and the winter of Copenhagen; and at Qubec, the summer of Paris and the winter of Petersburg. In China, at Pekin, for example, where the mean temperature of the year is that of the coast of Brittany, the scorching heats of summsaler are greater than at Cairo, and the winters are as rigorous as at Upsal."

The difference of climate between Europe and Eastern America, as determined by Humboldt in a paper on *Isothermal Lines and the Distribution of Heat over the Globe*, is as follows:—

The isothermal line of 32° passes in—
Europe, between Uleo and Enontakies, Lapland, ... Lat, 66° to 68°, E. Long. 19° 22′
America, through Table Bay, Labador, " 54° W. " 58°

The isothermal line of 41° passes in—
Europe, near Stockholm, . . . Lat. 60° E. Long. 18°
America, the Bay of St. George, Newfoundland, ... " 48° W. " 59°

The isothermal line of 50° passes in—
Europe, through Belgium, . . Lat. 51° E. Long. 2°
America, near Boston, . . " 42° 30′ W. " 70° 59′

The isothermal line of 59° passes in—
Europe, between Rome and Florence, Lat. 43° E. Long. 11° 40′
America, near Raleigh, North Carolina, " 36° W. " 11° 30′

Between the western part of Europe and the eastern coast of North America, the following differences generally obtain:—

Lat.	Mean Temperature of West of Europe	Mean Temperature of Eastern coast of North America.	Difference.
30°	70°. 52	66°. 92	3°. 60
40°	63°. 14	54°. 50	8°. 64
50°	50°. 90	37°. 94	12°. 96
60°	40°. 60	23°. 72	16°. 92

It is thus seen that the difference increases in proportion as high latitudes are attained. On the opposite coasts of the two hemispheres, the mean annual temperature decreases in the following ratio:—

	Lat.		Temp.		Temp.
From	0° to 20°	West of the old world.	3.° 60	East of the new world.	3.° 60
	20 — 30		7. 20		10. 80
	30 — 40		7. 20		12. 60
	40 — 50		12. 60		16. 20
	50 — 60		9. 90		13. 30
	0 — 60		40. 50		56. 50

The comparative difference of the seasons from the equator to the polar circle, is exhibited in the folowing table:—

Isothermal Lines.	Europe, Long. 1° W. to 17° E. Mean Lemperature.			America, 58° to 72° W. Long. Mean Temperature.		
	Winter	Summer	Difference.	Winter.	Summer	Difference.
68°	59° —	80.° 60	21.° 60	53.° 60	80.° 60	27.° —
59°	44. 60	73. 40	28. 80	39. 20	78. 80	39. 60
50°	35. 60	68. —	32. 40	30. 29	71. 60	41. 40
41°	24. 80	60. 80	36. —	14. —	66. 20	52. 20
32°	14. —	52. 60	93. 60	1. 40	55. 40	54. —

These various relations determined by Humboldt, are as correct as his data would warrant. The isothermal line of 41°, which, according to this philosopher, passes through the Bay of St. George in Newfoundland, in the latitude 48°, if correctly ascertained, sinks as it penetrates toward the interior of the continent; for at Hancock Barracks, Maine, in latitude 46° 10′, at a distance of 150 miles from the Atlantic, the mean annual temperature is 41.° 21, and at Fort Brady, at the outlet of Lake Superior, in latitude 46° 39′, it is 41°. 39; and proceeding to the western coast of America, we find that at Fort Vancouver, Oregon Territory, in latitude 45° 37′, the mean temperature, like similar parallels in western Europe, is as high as 51.° 75.

As those who first observed the climatic difference between western Europe and eastern North America, were natives of the former, they of course regarded the climate of their own country as constituting the rule, and that of America as the exception; but when men of science came to generalize these facts, it was discovered that the eastern coasts of both continents have a lower annual temperature than the western in corresponding latitudes. These results find a satisfactory explanation in physical causes, thus demonstrating the harmony of the laws of climate throughout the globe.

The rationale of these laws finds an explanation in a grand natural phenomenon, which may be designated the *great Atmospheric circulation*. The cause of these general atmospheric currents, which tend, in a remarkable degree to equalize the distribution of temperature over the surface of the globe, has been already pretty fully investigated. It was shown that there exist two grand currents, a *polar* and an *equatorial*, and that while the former produces easterly or trade-winds within the tropics, the latter is the cause of the prevalent westerly winds between the parallels of 30° and 50°. With so much uniformity in both hemispheres do these westerly winds blow that they are scarcely less deserving than the easterly inter-tropical winds of the name of *trade-winds*. We thus perceive at once the principal causes of the rise of the isothermal line on the western coast of continents, in extra-tropical latitudes; for there is thus swept from the ocean, which never sinks below the freezing point, a humid atmosphere, which, in its passage over the land, has a constant tendency to establish an equilibrium of temperature, and as its vapor is gradually condensed, it also evolves its latent heat. As large bodies of water never become so cold in winter or so warm in summer as the earth, the winds that sweep from them have a constant tendency to maintain an equilibrium of temperature. Land winds, on the contrary, must necessarily bear with them the greater or less degree of cold induced by congelation, whilst in summer, they will convey the accumulated heat absorbed by the earth; and thus is produced, in a great measure, those extremes of the seasons which characterize extra-tropical latitudes on the eastern coasts of continents. It is thus seen that the relative proportion of land and water exercises an all-controling influence in modifying climate—a fact strongly illustrated by the circumstance that the decrease of heat, as we recede from the equator, follows different laws in the two hemispheres. In the austral division of the globe, the annual temperature is lower, which arises from the circumstance that it contains less land—a cause which also produces a disparity in the duration of the seasons in the two hemispheres. The northern summer is eight days longer, and the winter is eight days shorter, than the southern. In the former, the heat of summer is, therefore, augmented, whilst the cold of winter is diminished.

This difference of temperature on the eastern and western coast of continents is still further increased by local causes. Europe is separated from the polar circle by an ocean, while eastern America stretches northward at least to the 82° of latitude. The former, intersected by seas, which temper the climate, moderating alike the excess of heat and cold, may be considered a mere prolongation of the old world; while the northern lands of the latter elevated from 3,000 to 5,000 feet, became a great reservoir of ice and snow, which diminish the temperature of adjoining regions.

"America," says Mr. Philips, "with little north tropical and wide north polar land, gives us a case of extreme refrigeration from the pole towards the equator; Africa and the West of Europe compose a surface of wide and hot north tropical land, with free channels to a polar sea." Thus Lapland, under the 72°, experiences a less rigorous climate than Greenland under the 60th parallel. On the other hand, between the 40th parallel and the equator, the influence of land, if not very elevated, produces effects diametrically opposite; for, the surface of the earth absorbs a large quantity of caloric, which is diffused by a radiation into the atmosphere. Thus Africa, as Malte-Brun observes, "like an immense furnace, distributes its heat to Arabia, to Turkey in Asia, and to Europe." On the contrary, the north-eastern extremity of Asia, which extends between the 60th and 70th parallel and is bounded on the south by water, experiences extreme cold in corresponding latitudes.

Another cause of the high temperature of Europe is, the Gulf-stream, which stretches across the Atlantic between Cape Hatteras and the Azores forming, nearly in the middle of the northern Atlantic, a lake of warm water, which, according to Major Rennell, is not inferior to the Mediterranean in extent. While a cold polar stream sweeping immense masses of ice into lower latitudes, is directed upon the coast of North America, the warm air of this ocean lake is wafted over the whole of the coasts of Western Europe, from Cape Finistere to North Cape; and these winds, it is said, even penetrate through the wide gate between the Hartz mountains and the Scandinavian ranges, into the recess of the Baltic.

As the Gulf-stream approaches much nearer to the coast of North America than to Europe, and as the temperature of its waters is also higher near the former, it may be objected that the effect here described, applies rather to the New than to the Old World. But this ocean-current along the coast of America is of comparatively inconsiderable width, being opposite Charleston only about sixty miles wide. At Cape Hatteras it turns to the east, and opposite the great bank of Newfoundland, after a course of 1,300 miles, its waters have lost only 5°, the temperature being 8°--10° above that of the adjacent seas. It is in these colder regions that the most marked influence of the Gulf-stream upon the temperature is manifested; and when we consider that here westerly winds prevail, it follows that by far the greater portion of the warm air arising from this source, must be wafted to countries lying to the leeward of these winds.

The western coasts of the two worlds, it appears, resemble each other only to a certain point. The coast of New California and the embouchure of the Columbia, according to Humboldt, are like that of Europe as far as 50° or 52° of latitude. From the same writer as well as Anglo—American travellers, we learn that at Nootka, in the island of Quadra and Vancouver, and almost in the latitude of Labrador, the smallest rivers do not freeze before the month of January. Near the mouth of the Columbia, Captain Lewis saw the first frosts on the 7th of January, and the rest of the winter he represents as mild and rainy. The climate of this region, however, has been already investigated in the preceding pages—an investigation based chiefly on thermometrical observations made by J Ball Esq. of Troy, N. Y., at Fort Vancouver, on the Columbia River.* These observations, it is true, embrace but a single year; but as the results confirm those of Humboldt and others, and as constant climes exhibit comparatively little annual variation in the phenomena of temperature, they are entitled to every consideration. Moreover, the region of Oregon having grown in public estimation, within a few years, into a very important part of our national domain, the inquiries consequently instituted by Congress in regard to its climate and productions, all coincide in the same results.

The following comparative view shows the difference between the mean temperature of winter and summer on the eastern and western coasts of the two continents:

Points of Comparison.	Isothermal Line.	Difference between the mean temp. of winter and summer.
America, Eastern coast,	53°.60	43° 60
Asia, Eastern coast,	53°.60	55°.80
Europe, Western coast,	53° 60	28° 30
America, Western coast,	51°.75	23°.70

The first three results on the same isothermal line are furnished by Humboldt. Unable to obtain the same annual temperature on our

* See Silliman's Journal, Vol. xxv. and xxviii.

Pacific coast, it becomes necessary to take a lower isothermal line, (that of Fort Vancouver,) which of course gives a contrast in the seasons correspondently greater. The table, however, shows conclusively that the climate of the New World, viewed in its general features, is, contrary to general opinion, less austere than that of the Old. Comparing our eastern coast with that of Asia, the difference between the mean temperature of winter and summer is found to be 12°.20 less; and comparing our western coast, (notwithstanding the isothermal line is lower,) with that of Europe, a difference of 4°.60 less is exhibited. It may be well to add that, with the exception of the last, the author is not aware of the local position of these points of comparison—a consideration of some importance, inasmuch as the Northern Division of the United States presents, on the same isothermal line, a difference between the mean temperature of winter and summer, varying from 38° to 54°.

Independent of the westerly winds, which transport the tempered atmosphere of the Pacific over the land, and conversely, in traversing the continent, bear upon their wings the accumulating cold towards our eastern shores, we observe, in attempting to account for the extraordinary dissimilitude in the climate of our two coasts, on the eastern side an unascertained prolongation of the continent towards the pole and an oceanic current sweeping immense masses of ice southwardly, whilst on the western side, the great range of Rocky Mountains shelters Oregon from the polar winds, and the projecting mass of Russia America protects it from the polar ice.

Connected with this subject is the question frequently agitated, whether the Old Continent is warmer than the New. Volney and others have attempted its solution by a comparison of the mean annual temperatures of different places on both sides of the Atlantic; but to this mode of determining it, the objection at once presents itself, that the points of comparison represent opposite extremes in the climate of each continent. Indeed, the question in itself involves an absurdity; for, as the laws of nature are unvarying in their operation, and as similar physical conditions obtain in corresponding parallels of both continents, the same meteorological phenomena will be induced. It shows in lively colors the truth of the remark, that every physical science bears the impress of the place at which it received earliest cultivation. In geology, for example, all volcanic phenomena were long referred to those of Italy; and in meteorology, the climate of Europe has been assumed as the type by which to estimate that of all corresponding latitudes. In making a comparison of the two continents, it is, therefore, necessary that both points have the same relative position. Fort Sullivan, Maine, notwithstanding it is more than 11° south of Edinburg, Scotland, exhibits a mean annual temperature 5½° lower; Bordeaux, which is parallel with Fort Sullivan, has an annual temperature 15° higher; and the mean of Stockholm, in lat. 59°20′, is about the same as that of Fort Sullivan, in lat. 44°44′. These are not, however, legitimate points of comparison. Pekin and Philadelphia, each on the eastern coast of its respective continent, are fair examples, having the same latitude and a similar relative position, and consequently the same mean annual temperature. A comparison between Western Europe and the United States would be equally improper with a comparison between it and China. "Thus at Pekin, in lat. 40° N., long 116°20′ East," says Dr. Traill,* "the mean temperature of summer is 78°8, and of winter 23°—a difference of not less than 55°.8, which gives rise to a frost of several months' duration in that part of China; yet Pekin is under the same parallel as the southern extremity of Naples, where frost is unknown, and of the central provinces of Spain, in which, though at an elevation of 2000 feet above the sea, ice is an extremely rare occurrence."

In the table, as arranged by Humboldt, of the comparative difference of the seasons in Western Europe and Eastern America, from the equator to the polar circle, given on a preceding page, the results, owing of course to the paucity of his data, are not characterized by much precision. As the region of the United States exhibits very diverse systems of climate even on the same parallells, such comparative tables can present only the most general laws. For instance, it shows that on the isothermal line of 41°, the mean temperature of winter is 14°, and that of summer 66°.20—a result obtained from observations made in lat. 48° on the Bay of St. George, Newfoundland. Now, according to the "Army Meteorological Register," this isothermal line is again found in the comparatively equalized climate of Fort Brady, at the outlet of Lake Superior, in lat 46° 39′, where the mean temperature of winter is as high as 21°.07, while that of summer is only 63°.18. Again, the table shows that on the isothermal line of 50°, the mean temperature of winter is 30°.20, and that of summer 71°.50; but this too gives only a partial view, as at Fort Wolcott, Rhode Island, the former is 32°.51 and the latter 69°.06, and at Council Bluffs, near the junction of the Platte and Missouri, 24°.47 and 75°.82, thus showing that the disparity in the mean temperature of winter and summer, on the same parallel of latitude and on the same isothermal line, (that of Fort Wolcott being 50°.61 and that of Council Bluffs 51°.02,) is 14°.80 greater in an *excessive* than in a *uniform* climate.

It is only within the temperate zone, from 30° to 60° of N. latitude, that the year exhibits the grateful vicissitudes of the four seasons—the varied charms of spring and autumn, the tempered fires of summer, and the healthful rigors of winter. Wisdom desires not that "eternal spring," the want of which poets affect to deplore. At the equator, there is no difference between the mean temperature of summer and winter, but it increases, as a general rule, with the latitude. From Florida to Canada, the contrast in the seasons increases in proportion as the mean annual temperature decreases—a general law subject to modification on every parallel in accordance with the varieties in physical geography. The greatest and the least contrasts of winter and summer are exhibited at Fort Snelling and Key West; but as this point has been already sufficiently elucidated, it may be well to bring at once under notice a few of the laws determined by Humboldt.

"The winters of the isothermal curve of 68°," he says, "are not found upon that of 51°, and the winters of 51° are not met with on the curve of 42°. In considering separately what may be regarded as the same systems of climate, for example, the European region, the Transatlantic Region, or that of Eastern Asia, the limits of variation become still more narrow. Wherever in Europe, in 40° of long., the mean temperature rises—

To 59°.—	the winters are from	44°.60 to 46°.40	and the summers from	73°.— to 75°.—
" 54° 50		36°.50 " 41° —		68°.— " 73°.—
" 50°.—		31°.10 " 37°.40		62° 60 " 69°.90
" 45°.50		28°.40 " 36°.10		57°.20 " 68°.—
" 41°.—		20°.30 " 26° 80		55°.40 " 66°.—

In the United States, if the comparison is confined to the same system of climates, as for example the posts on the ocean or lakes, or those remote from the agency of large bodies of water, the limits of variation, as in Europe, are also narrow; but if the whole extent of our domain is embraced, the results are strikingly diverse. Thus—

	MEAN TEMPERATURE.		
	Annual	Winter.	Summer.
Fort Vancouver, Oregon Terrrtory, . . .	51°.75	41°.33	65°.—
Council Bluffs, junction of Platte and Missouri,	51°.02	24°.47	75°.82
Difference, ...	0°.73	+16°.86	—10°.82

Here then, although there is not a degree of difference in the mean annual temperature of Fort Vancouver and Council Bluffs, yet the mean winter temperature of the latter is nearly seventeen degrees *lower*, while the mean summer temperature is nearly eleven degrees *higher*. But this contrast is exhibited in a still more marked degree, by comparing the difference between the mean temperature of winter and summer, the former being 23°.67, while the latter is 51°.35.

"In tracing five isothermal lines between the parallels of Rome and St. Petersburg," continues Humboldt, "the coldest winter presented by one of these lines is not found again on the preceding line. In this part of the globe, those places whose annual temperature is 54°.50, have not a winter below 32°, which is already felt upon the isothermal line of 50°."

In the European climate, two points having the same winter temperature may differ as much as 11° in latitude. Thus in Scotland, in latitude 57°, and isothermal line 45°.50, the winters are more mild than at Milan, in latitude 45° 28′, and isothermal line 55°.80. Consequently the lines of equal winter cut isothermal lines which differ 10°. At the isle of Maggeroe, at the northern extremity of Europe, under the parallel of 71°, the winters are 7° milder than at St. Petersburg, latitude 59° 56′. In the United States, embracing the whole region between the Atlantic and the Pacific, as great a contrast no doubt exists. The mean winter temperature of Fort Vancouver, Oregon Territory, latitude 45° 37′, is found about 9° farther south at a point intermediate to Fort Gibson and Jefferson Barracks; but if the observations, like those in Scotland just referred to, were made on the coast, (Fort Vancouver being 70 miles distant from the Pacific,) the winter temperature would necessarily be still higher. As the mean annual temperature of Fort Vancouver is 51°.75, and that of the assumed point between Fort Gibson and Jefferson Barracks is about 61°, it follows that the lines of equal winter cut isothermal lines which differ more than 9° of Fahrenheit. [See map of the United States]

In Europe a greater deviation from the terrestrial parallels is caused by the inflections of the isocheimal than by the isothermal lines; for while two points having the same winter temperature may differ as much as 11° in latitude, a difference of not more than 5° is found between any two places having an equal annual temperature—disparities which increase as the eastern coast of Asia is approached. In the United States, the same law obtains; for between the isothermal line of Fort Vancouver and the same in the Atlantic region, the difference is only 4° of latitude. [See map of the United States.]

The isotheral curves or lines of equal summer follow a direction opposite to that of the isocheimal lines. The region about Moscow and that about the mouth of the Loire, in France, notwithstanding differing 11° in latitude, present the same summer temperature. Although this result as regards difference of latitude, is not discovered in the United States, yet the most extraordinary results in this respect have been demonstrated on the same parallel running from the Atlantic through the great lakes. In the United States, the heats of summer are everywhere intense. At Fort Snelling, notwithstanding the isocheimal line is 54° lower than at Key West, the isotheral is only 8° lower. (See plate.) At Fort Vancouver, the mean summer temperature is 2° or 3° higher than on the same parallel in the region of the Atlantic and the great lakes, and about 7° lower than in the excessive climates of the same region. In tracing an isothermal line around the globe, we find that the same causes which, on the Atlantic coast of North America and in the north of China, depress the curves of equal annual heat, tend to elevate the isotheral curves or lines of equal summer.

The general and partial inflections of isothermal, isocheimal, and isotheral lines, might be advantageously represented on charts, as shown in the two diagrams connected with this chapter. These graphical representations would throw light upon phenomena having a close relation to agriculture and the physical and political condition of mankind. Instead of tracing all these curves on the same chart, it would be advisable merely to add the indications of the mean temperature of summer and winter to the isothermal lines at their summits and depressions. Thus, in following the line of 51°, we find it marked in England $\frac{37^\circ.90}{62\ .80}$, in Hungary $\frac{31^\circ.30}{70\ .10}$, in China $\frac{24^\circ.10}{79\ .20}$, in Western America, at Fort Vancouver $\frac{41^\circ.38}{65\ .00}$, and in Eastern America, at Council Bluffs $\frac{24^\circ.47}{75\ .82}$, and at Fort Wolcott, Rhode Island, $\frac{32^\circ.51}{69\ .06}$.

It has just been remarked that the variations in the seasons on the same isothermal line should be marked at its "summits and depressions," thus implying, as is generally believed, that the causes, which produce inflections in the line of equal annual temperature, have a similar effect on the isotheral and isocheimal lines. This deduction is based on the law that the same causes which produce the greatest convexity of the isothermal line, also equalize the temperature of the seasons, as is proved by its convex summits on the western coasts of the Old and the New World, compared with the concave inflections on the eastern coasts. Thus the annual mean temperature being equal to the fourth part of the total of the winter, spring, summer, and autumnal

* Encyclopædia Britannica.

temperatures, the same isothermal line of 53.°60, as given by Humboldt, shows—

	Winter. Spring. Summer. Autumn.
At the *concave* summit in America, 74° 40′ west longitude,	$53.^\circ60=\frac{32.^\circ\text{[illegible]}+52.^\circ30+75.^\circ60+54.^\circ50}{4}$
At the *convex* summit in Europe, 2° 20′ west longitude,	$53.^\circ60=\frac{40.^\circ10+51.^\circ80+68.^\circ40+54.^\circ10}{4}$
At the *concave* summit in Asia, 116° 20′ east longitude,	$53.^\circ60=\frac{24.^\circ80+54.^\circ70+80.^\circ60+54.^\circ30}{4}$
At the *convex* summit in America, at Fort Vancouver, in lat. 45° 37′ and long. 122° 37′, according to the "Army Meteorological Register,"	$51.^\circ75=\frac{41.^\circ33+48.^\circ00+65.^\circ00+52.^\circ67}{4}$

It is thus seen that on the western coasts, where the isothermal curve rises, or is *convex*, the seasons are much equalized, the difference between the mean temperature of winter and summer being only about one-half as great as on the eastern coasts, where the line sinks, or is *concave*. The precise difference is shown in a table already given.

But this law, that the same causes which increase the mean annual temperature also equalize the seasons, does not hold good in the United States, in receding from the Atlantic; for, on comparing the climate of the coast of New England with the still more excessive climate of the interior, it is found that the mean annual temperature of the latter is higher.

That the climate should become more austere, the seasons being less equalized, is in accordance with the laws established by Humboldt; but that the isothermal line, at the same time, should become more *convex*, is in diametrical opposition.

Forts Sullivan, Snelling, and Howard, for example, have very nearly the same latitude: the first, on the ocean, has a mean annual temperature of 42.°95, while the last two in the opposite system of climate, have a mean respectively of 45.°83 and 44.°92—a result the more unexpected, at first sight, as the latter are in a region elevated 600–800 feet above the level of the sea. Comparing Fort Wolcott, on the ocean, with Fort Armstrong, West Point, and Council Bluffs, in the interior, the same relation is found. Fort Trumbull, it is true, offers an exception; but it is necessary to bear in mind that the results of this post are based on two years' observations only, while those of Fort Wolcott are calculated from ten; and in further evidence of its erroneousness, it may be mentioned that the mean annual temperature at Fort Columbus, which is 0° 40′ farther south than Fort Trumbull, based on nine years' observations, is 2° less. Again, we find that while at Salem, near the Atlantic, in lat. 42° 34′, the mean annual temperature, based on thirty-three years' observations, is 48.°61, it is, on the other hand, at Fort Armstrong, lat. 41° 28′, Council Bluffs, lat. 41° 45′, and at West Point, lat. 41° 22′, respectively 51.°63, 50.°50, and 52.°47. Here then is actually an increase of from two to four degrees in the annual temperature, while the interior posts are only about 1° nearer the equator, which cannot, on the average, cause a greater difference of temperature than 1.°50.

Having thus shown that there is an actual increase of annual temperature, or a rise of the isothermal line, on receding westward from the Atlantic, it is deemed unnecessary to give any details proving that, instead of the seasons becoming from the same causes more equalized, they actually grow more contrasted, inasmuch as this law has been already abundantly established. Suffice it to compare Fort Snelling on the Mississippi and Fort Sullivan on the Atlantic. Although the former has a mean annual temperature 2.°88 higher than that of the latter, yet it has a contrast between the mean temperature of winter and summer actually 17.°45 greater! Equally striking is the contrast between the results given by the posts on the lakes, and those in the same region, notwithstanding not more than one, two, or three hundred miles distant. Thus on comparing Forts Snelling and Howard with positions, (Forts Brady and Mackinac,) in the modified climate of the lakes, this relation is discovered; for, although the mean latitude of the latter posts is only 1° 34′ north of Fort Snelling, (and perhaps 400 miles distant,) yet the mean annual temperature is 4.°25 lower. Now, of this difference in annual temperature, not more than one half can be accounted for by difference of latitude, being an expression of the same law that was revealed by the comparison with posts modified by the ocean; and we also find that, so far from the temperature of the seasons being more equalized at Fort Snelling, which has a higher annual temperature, the difference between the mean temperature of summer and winter is in reality 12.°84 greater than on the lakes.

Humboldt's law holds good so far as the comparison refers to the eastern and western continental coasts, each being more or less modified by the ocean; but in a comparison with an interior position remote from large bodies of water, a new element, arising from the law of the accumulation of caloric by the surface of the earth, doubtless enters into the calculation. It may be said, however, that this ought to be compensated by the augmented cold of winter; but it is found in our excessive climates, compared with the modified, that the annual temperature gains more by the continued elevation of the thermometer in summer than it loses by its depression in winter. Besides, in excessive climates, the vernal increase alone often compensates for the low temperature of winter; for example, although the mean winter temperature at Fort Sullivan is 22.°95 and at Fort Snelling as low as 15.°95, yet that of spring is higher at the latter, being as 46.°78 to 40.°11. Then follows a mean summer temperature more than 10° higher in the excessive than in the uniform clime. The season of autumn, (September, October, and November,) is not perceptibly influenced by these causes.

These contrasts would be still more striking, were the comparisons instituted between points on the same isothermal line, instead of the same parallel of latitude: for, as the isothermal curve of Fort Sullivan would strike a point at least 2° north of Fort Snelling, the extremes of the seasons there would be correspondently augmented. Sufficient, however, has been adduced to prove that Humboldt's deduction, *that the same causes which produce the greatest convexity of the isothermal line, also equalize the temperature of the seasons*, is unwarranted as a general law. And here the author may venture to add that these conclusions pertain wholly to himself, inasmuch as they had been, doubtless, never brought to the notice of the scientific world, before they were made known by him in his work on "The Climate of the United States and its Endemic Influences."

These results, in the comparisons just made, appear the more extraordinary, as some reduction of temperature, by reason of the elevation of these interior posts, would be *a priori* inferred; for, according to Humboldt, "elevations of 400 metres, (1,312 feet,) appear to have a very sensible influence on the mean temperature, *even when great portions of countries rise progressively*." That high table-lands have a more exalted temperature than isolated mountains of the same height, is well known; for the elevated plains on which the towns of Bogota, Popayan, Quito, and Mexico are built, have a much warmer climate than they would have, if elevation above the sea were the only element that determines the temperature when the latitude is given. That our western table-lands rising gradually to the height of 800 feet, cause no diminution of temperature, has been already abundantly established. Although at Fort Mackinac, situated on the island of the same name, the temperature of the seasons is as much equalized as on the Atlantic, yet the annual temperature, notwithstanding it is only 1° farther north than Fort Snelling, is 5.°27 lower. Moreover, as Fort Mackinac is elevated about 150 feet above the surface of the lake, its height above the sea is probably the same as that of Fort Snelling.

Although the causes upon which the diminished temperature in the higher regions depends, have been already satisfactorily explained when speaking of the limits of perpetual snow, yet the preciseness of the following explanation by M. Arago in reference to the same point, will serve as an apology for its introduction: "L'atmosphère est très peu échauffée par le passage des rayons solaires: elle doit donc être plus froide que la surface de la terre; et par la même raison, les hautes montagnes et les terres les plus exposées à l'action de l'atmosphère, doivent toujours être plus froides que les lieux situés à peu près au niveau de la mer. L'atmosphère doit aussi, comme l'expérience l'a prouvé, être d'autant plus froide qu'on s'y élève davantage: en effet, tous les corps renferment une certaine quantité de calorique rendu latent et insensible: la grande chaleur émise par la vapeur d'eau qui se condense, en est une preuve évidente: or l'air contient d'autant plus de calorique latent, qu'il est plus raréfié; ce que démontre aussi *le briquet à air* en rendant libre, lorsqu'on le comprime, assez de chaleur pour enflammer un morceau d'amadou: l'air absorbant peu de chaleur par rayonnement, et, au contraire, beaucoup par le contact, il en résulte qu'il doit s'établir un courant ascendant d'air qui se dilate, lorsqu'il est parvenu à une certaine hauteur, et produit du froid, en absorbant une quantité de calorique nécessaire pour maintenir cette dilatation. Il devra donc, si des corps plus chauds se recontrent dans ces régions élevées, les refroidir beaucoup en leur enlevant le calorique qui lui manque."—[*Traité de Météorologie, ou Physique du Globe, par Garnier.*

Now it is apparent that these causes cannot be in operation when a large region of country rises very slowly and progressively to a height less than 1000 feet. It is only when lands are considerably and suddenly elevated, and exposed to the action of the atmosphere laterally, that this rapid conduction of heat and rarefaction of the atmosphere can take place. When large tracts of country rise gradually, the decline of 1° of temperature for every 300 feet of elevation, as determined either by a balloon ascension or scaling the sides of isolated and precipitous mountains, does not by any means take place. Our north-western region, in those districts which are remote from the great lakes, for example, so far from causing a diminution of annual temperature, produces, in consequence no doubt of the great accumulation of summer heat by the soil, an augmentation. A most striking illustration of an analogous fact is afforded by the ridges and valleys of the great Himmaleh Mountains of Southern Asia, where immense tracts, which theory would consign to the dreariness of perpetual congelation, are found richly clothed in vegetation and abounding in animals. At the village of Zonching, 14,700 feet above the level of the sea, in lat. 31°36′ N., Mr. Colebrook found flocks of sheep browsing on verdant hills; and at the village of Pui, at about the same elevation, there are produced, according to Capt. Gerard, the most luxuriant crops of barley, wheat, and turnips, while a little lower the ground is covered with vineyards, groves of apricots, and many aromatic plants.

As the geographical distribution of plants and animals appears to be chiefly regulated by the temperature of the atmosphere, there are many other relations developed in the tabular abstracts appended to the author's work on the climate of the United States, useful to him disposed to classify facts of this kind. July, taking the mean of a series of years, is, throughout the United States, the hottest month in the year, with scarcely an exception; and January, generally speaking, is the coldest month, but sometimes December or February gives a lower temperature. The least difference between the mean temperature of any two successive months, is that of July and August, and the next lowest is that between January and February. Between October and November, the difference is greatest at the southern posts; but at the northern, on the ocean and on the lakes, the difference between March and April, and between April and May, is about the same as that between October and November, whilst in the localities remote from large bodies of water, in these northern regions, the difference between October and November, is generally less than that of either of the two former. This last result arises from the circumstance that in excessive climes the increase of vernal temperature is very great.

The influence of temperature on the geography of plants, is ably pointed out by M. de Candolle. In considering its relation with the organic life of plants, it is necessary to keep in view three objects:—1. The mean temperature of the year; 2. The extreme of temperature both in regard to heat and cold; 3. The distribution of temperature among the different months of the year. The last is the most important; but in the investigation of vegetable geography, it is requisite to estimate the simultaneous influence of all physical causes,—soil, heat, light, and the state of the atmosphere as regards its humidity, serenity, and variable pressure. Each plant has generally a particular climate in

which it thrives best, and beyond certain limits it ceases to exist. Hence having seen the great variations of summer and winter temperature on the same isothermal line, the absurdity of limiting a vegetable production to a certain latitude or mean annual temperature, is apparent. To say that the vine, the olive, and the coffee-tree require, in order to be productive, annual temperatures of 53°.60, 60°.80, and 64° 40, is true only of the same system of climate. As the annual quantity of heat which any point of the globe receives, varies very little during a long series of years,* the variable product of our harvests depends less on changes in the mean annual temperature, than in its distribution throughout the year. Thus climates in regard to vegetable productions, are strongly characterized by the variations which the temperature of months and seasons experience. As this subject is too extensive for present consideration, reference will here be made only to some peculiarities in the climate of the United States. The cotton-plant finds its most favorite climate between the equator and latitude 34°; but it succeeds with a mean summer temperature of 75° or 73°, if that of winter does not descend below 36° or 38°. In the United States, it is cultivated in latitude 37°, and in Europe in latitude 40°. Whilst the sugar cane is cultivated in Europe as far north as latitude 36°, in a mean annual temperature of about 67°, its cultivation in the United States, on account of the low winter temperature, is prevented beyond latitude 31°; but it succeeds on the great table-plain of Mexico and Guatimala, where an altitude of 6000 feet converts a tropical into a temperate climate. In Europe, the olive ranges between latitude 36° and 44°, that is, in a mean annual temperature from 66° down to 58°, provided the mean temperature of summer is not below 71°, nor that of the coldest month below 42°, which last excludes all the United States beyond latitude 35°. For the same reason, the date, palm, and sweet orange, grow in Louisiana only to latitude 30°. In Europe, the favorite climate of the vine is between latitude 36° and 48°, that is between the isothermal lines of 62° and 47.°50, provided the winter line is not below 33°, nor the summer under 66° or 68°. Snch is the case in Europe to latitude 40°; but on the Pacific coast of our territory, the requisite temperature is found at Fort Vancouver, which is in the latitude of Montreal. Here vegetation grows luxuriantly in mid-winter. That vegetables common to the warm climates, as the orange, lemon, citron, fig, olive, and pomegranate, can be successfully cultivated here, is no longer a doubtful question; and the cotton-plant also, is said to flourish well. The British Fur Company at Fort Vancouver, besides cultivating all these plants, have likewise a fine grapery, which yields fruit equal to those in France.

The influence of the unequal distribution of heat upon vegetable geography is beautifully illustrated in the four systems of climate demonstrated on the same parallels in the Northern Division of the United States; and if we extend the comparison to the Pacific coast, a fifth system may be enumerated on the same latitude. Taking the coast of New England, the region of the great lakes, and the Pacific coast, the difference between the mean temperature of winter and spring varies from 6.° 67 to 18.° 42; while in the excessive climate of the region west of the lakes, and that intermediate to the lakes and the Atlantic, this difference ranges from 18.° 82 to 30.° 83; and accordingly we find, as already explained, that spring and summer, in the latter, are confounded with each other, and that the sudden excess of heat renders the progress of vegetation almost perceptible. It is necessary, however, to add that the low ratio of 6.° 67 occurs on the Pacific coast, the lowest average in the Northern Division of the United States being 11.° 67. In the Middle and Southern Divisions, this vernal increase of temperature gradually diminishes, until finally at Key West it is only 5.° 99. But there is another important feature to be observed. Not only is the vernal increase greater in excessive climes; but as it supervenes upon a lower winter temperature, the effect produced on the development of vegetation is in an inverse ratio. The vernal increase of 30.° 83, for example, at Fort Snelling, comes upon a mean winter temperature of 15.° 95, while at Fort Sullivan, on the same parallel, the increase of only 17.°16 follows a winter temperature as high as 22.°95. Between northern and southern latitudes, this contrast is still more marked; for, while at Fort Snelling there is a difference of 13.° 46 between the months of February and March, and at Key West only 1.°56, the temperature of February at the former is 18.° 66 and at the latter 72.° 15.

This subject, too, has been set in a clear light by that oracle of nature, Humboldt. In regard to the climate of Europe, he determined—1, That whenever the division of the heat among the seasons is very unequal, the increase in the vernal temperature is very great, (from 14.° 40 to 16.° 20 in the space of a month,) and equally prolonged; 2. That in the temperate portion of Europe, the vernal increase is great, (from 9° to 10.° 80,) but little prolonged; 3. That in an insular climate, the increase of the vernal temperature is small, (scarcely 7.° 20,) and equally prolonged; and 4. That the vernal increase, in every system of climate, is smaller and less equally prolonged in low than in high latitudes.

In regard to the extremes of heat and cold in the United States, it would be natural to expect that the severest cold would be registered at the most northern, and the greatest heat at the most southern posts. It is now, however, proved by exact instrumental observations that this is not the case, as these are situated on large bodies of water; but that the western stations, Forts Snelling, Gibson, and Council Bluffs, remote from inland seas, are remarkable for extremes of temperature. It is here that the mercury rises the highest and sinks the lowest, while Forts Brady and Mackinac, the most northern stations, as well as those on the southern coast, exhibit a lesser range of the thermometer; and in accordance with the same law, we find that the mean summer temperature is greater at Augusta, Georgia, than along the coast of Florida. While at Key West, during a period of six years, the thermometer never rose above 90°, it attained at Council Bluffs, a point 17° 12′ farther north, a height every year varying from 102° to 108.° The highest temperature in the shade noted at our various posts, was at Fort Gibson, on the 15th of August, 1834, being 116°.* In Africa, the mercury is sometimes seen at 125°, and in British India it is said to have been as high as 130.° It has been remarked that on the coast of Senegal the human body supports a heat which causes spirits of wine to boil, and that in the northeast of Asia, it resists a cold which renders mercury solid and malleable. Although the mean annual temperature, in proceeding from the equator towards the poles, gradually diminishes, yet the thermometer scarcely mounts higher at the equinoctial line than under the polar circle. Hence it follows that the climate of the tropics is characterized much more by the duration of heat than its intensity.

Although the thermometer may be 15° or 20° higher here than in England, during the heats of Summer, yet we suffer but little more from its effects; for, as the air of the latter country is more loaded with humidity, causing a diminution of the cutaneous and pulmonary transpiration—the evaporation of which constitutes a cooling process—a langour and a listlessness with an indisposition to mental and corporeal exertion, are induced. In the transition of the air from a state of dryness to humidity, the indication of the barometer is distinctly at variance with our ordinary feelings. In damp weather, individuals of a delicate and enfeebled constitution, are wont to complain of the heaviness and inelasticity of the atmosphere; but moisture, so far from loading the air by its weight, causes, like heat, increased expansion and elasticity. It has been calculated by Mr. Epsy that when the dew-point is 30°, we evaporate from the lungs one pound of vapor for every thirty-five pounds of air that we breathe; and that, when the dew-point is 75°, we evaporate from the lungs one pound for every sixty-nine pounds. Hence in Summer, when the dew-point is very high, the quantity of vapor evaporated from the lungs, is not more than half as great, as in Winter, when the dew-point is very low. Moreover, as an atmosphere charged with vapor acquires highly conducting properties, positive electricity, which is doubtless a vital stimulus, is rapidly carried off from the animal system. The depressing Sirocco is nothing more than an atmospheric current having a high dew-point, and being perhaps, at the same time, in a relatively low electric condition, or being in a negative state, thus attracting the positive electricity of the human frame. The experiments of John Davy Esq., however, do not, as is shown in Chap. I, show any difference of electrical condition.

It is a generally received opinion, that in latitudes above 60°, the month that has the highest temperature is June, that in the more temperate regions it is July, and as we approximate the equator, August. Although July, with the exception of Jefferson Barracks and Fort Gibson, is the hottest month of the year at all the military posts of the United States, yet the law receives corroboration in the fact that the excess diminishes with the decrease of latitude. This result finds an explanation in the laws which regulate the earth's motion; for in latitudes beyond 60°, the sun's power is greatest at the Summer solstice; while below this point, the parallels continue to receive additional heat for sometime during his decline in the ecliptic, which tends to augment the temperature of the atmosphere. This subject is ingeniously explained by Garnier. To comprehend the influence of the sun, it is necessary to observe that its action is not manifested instantaneously, but that the heat produced is the effect of this action prolonged. The heat of day does not attain its maximum until sometime after the sun has passed the meridian; and in regard to the year, the same law obtains, for the greatest solstitial height is in June. The solar rays, at this period, continuously strike the earth almost perpendicularly during sixteen hours; and the heat thus accumulated during the day, cannot dissipate itself by radiation during the eight hours of the night. As this accumulation continues until the length of the night counterbalances that of the day, the maximum of heat is attained in July and August. As the torrid zone has nearly at all times a vertical sun, the temperature is there continuously high. In the frigid zones, as the solar rays are received very obliquely, and as the days and nights are alternately of long duration, the cold is excessive; while the temperate zones, which receive the sun under a mediate inclination, and are not exposed to long alternations of day and night, preserve a mean temperature.

The same law does not of course obtain at sea. The surfaec of the sea, in the middle of the ocean, and far from the influence of land, experiences a much smaller diurnal change of temperature than the surface of land. While in the equatorial regions the difference between the maximum and minimum diurnal range of the thermometer on land often amounts to 9° or 10°, the difference at sea is said to be seldom more than 3° or 4°. In temperate regions, the extreme diurnal range at sea is only 4° or 6°, while upon the continents the range often amounts to 30° or even 40°. It is thus easy to understand why small insular situations have more equable climates than continents. From a series of hourly observations made during a whole year at Frankford Arsenal near Philadelphia, the mean daily extreme range would seem to be about 30° for that locality. The following extract from Capt. Mordecai's report, by whom these observations were conducted, will serve to show the difference in this respect between our climate and that of England:—"Thus it will be seen that there is in some parts of almost every month, a variation as great as 12° in the mean temperature of two consecutive days; and that, in the winter and spring, this variation often extends to 15° or 18°. In Mr. Harris' register of observations during two years at Plymouth, England, there is only *one* instance of a difference exceeding 8° in the mean temperature of two consecutive days, and but two other instances of a difference as great as 8°. The extreme range of temperature at Plymouth, in 1834, was 48°, just one-half of the range at Frankford Arsenal in 1835–6."

As on land, the minimum temperature at sea takes place about sunrise; but while the maximum upon land takes place from two to three

*"The mean annual temperature of London," says the Rev. William Whewell, in his Astronomy and General Physics, "is 50 degrees 4-10ths. The frost of the year 1788 was so severe that the Thames was passable on the ice; the mean temperature of that year was 50 degrees 6-10ths, being within a small fraction of a degree of the standard. In 1796, when the greatest cold ever observed in London occurred, the mean temperature of the year was 50 degrees 1-10th which is likewise within a fraction of a degree of the standard. In the severe winter of 1813-14, when the Thames, Tyne and other large rivers in England were completely frozen over, the mean temperature of the two years was 49 degrees, being little more than a degree below the standard. And in the year 1808, when the summer was so hot that the temperature in London was as high as 93½ degrees, the mean heat of the year was 50½, which is about that of the standard."

* It may be worthy of remark that when this observation was made by Dr. J. B. J. Wright, of the Army, he had the benefit of two thermometers, one of which indicated 117.° Moreover, the instruments were in a situation unaffected, as much as possible, either by the direct or reflected rays of the sun, or by radiation of heat from surrounding bodies

hours after noon, it occurs at sea about, or very soon after, meridian. The maximum atmospheric temperature between the tropics, is said to be somewhat higher than that of the surface of the ocean; but when the daily means, taken every four hours, are compared, the result would seem to show that the surface of the sea has a higher temperature than the incumbent atmosphere. Between the tropics and the fiftieth parallel, the air is seldom warmer than the surface of the sea; and in the polar regions, it is almost always much colder. In these seas, the annual variations of the weather are expended on the superficial waters, without disturbing the vast abyss below; and contrary to what occurs under milder skies, as has been already shown, the water drawn from a considerable depth has generally a higher temperature than that on the surface; and consequently the floating ice, from the slow communication of the heat sent upwards, begins to melt mostly on the under side.

Here we observe a beautiful provision of Nature for mitigating the excessive inequality of temperature. As in the process of freezing, the evolution of heat checks the decline of temperature, the inequalities of the seasons in the Arctic regions are being constantly tempered by the freezing of the water and the melting of the ice. As the rigor of winter, when darkness resumes her reign, is mitigated by the heat evolved as congelation spreads over the watery surface, the land animals and plants are thus saved from destruction. On the contrary, the fields of ice, and vast beds of snow, which cover the land and the sea in those dreary wastes, absorb, in the act of thawing or returning to the liquid state, the intense heat produced by a nightless summer. In the Arctic regions, were they entirely of land, neither plants nor animals could exist; for the incessant beams of summer, and the intense cold and long darkness of winter, would prove equally fatal to animated beings. By this beautiful arrangement, the surface of the ocean itself, by its alternate congelation and liquifaction, presents a vast substratum, on which the excesses of heat and cold are mutually spent. As long as water exists to freeze, or ice to thaw, the surplus heat of summer is expended in the one and its deficiency in winter supplied by the other, the temperature of the atmosphere being thus confined within certain limits.

The same laws operate to a limited extent in temperate regions, it being well known that the temperature of the air during a thaw is generally colder than when the ground is actually covered with ice—an effect produced by the absorption of heat from the atmosphere. Upon the same principle, a frost raises the temperature; for when water assumes the solid state, it gives out as much heat as it receives during the process of liquefaction.

What month expresses the nearest equivalent to the mean annual temperature? In regard to this question, there is considerable diversity of sentiment. According to Kirwan, it is the month of *April*, whilst Humboldt shows by tabular statements that *October* is better entitled to this characteristic. As the laws of nature are universal, these phenomena, like all others, must be susceptible of systematic arrangement; and lest it may be thought presumptuous in the author to attempt to decide between such high authorities, he will state in advance that the diverse systems of climate presented in the United States, more especially on the same parallels in the Northern Division, afford a means of comparison doubtless heretofore unequalled. A careful examination of the tabular extracts appended to the author's work on the Climate of the United States, will show that in *excessive* climates the mean temperature of April is generally as high as that of the year, while that of October is considerably higher; and in regard to *modified* climes, it will be found that the former is generally as much lower as the latter is higher. Now this relation is precisely what might have been anticipated; for, as the vernal increase of temperature is always much greater in excessive than in modified climates, it follows that, if under any circumstances April expresses a nearer equivalent than October, it must be when its mean temperature is augmented by a sudden vernal increase. These results, comprising some of the posts in the northern division of the United States, are exhibited in the following table:—

EXCESSIVE CLIMATES *Remote from large bodies of Water.*	No. of years of Observations.	MEAN TEMPERATURE *Year*	 *April*	 *Oct'r.*
Hancock Barrracks,	2	41°.21	43°.85	45°.84
Fort Snelling,	8	45 .83	46 .00	49 .27
Fort Howard,	9	44 .92	43 .28	47 .51
Council Bluffs,	5	51 .02	51 .82	53 .65
Fort Armstrong,	4	51 .64	51 .26	54 .58
MODIFIED CLIMATES *On the Ocean and Lakes.*				
Salem, Massachusetts,	33	48°.61	46°.11	51°.15
Fort Vancouver,	1	51 .75	46 .00	54 .00
Fort Brady,	6	41 .39	38 .50	45 .52
Fort Sullivan,	5	42 .95	43 .28	47 .51
Fort Preble,	5	46 .67	45 .44	49 .28
Fort Niagara,	2	51 .69	47 .52	58 .94
Fort Constitution,	4	47 .21	45 .31	50 .43
Fort Wolcott,	9	50 .61	46 .41	54 .45
Fort Trumbull,	2	55 .00	51 .00	58 .10
Fort Columbus,	9	53 .00	49 .89	55 .82

It is thus seen that in excessive climates, the law above stated holds good invariably. There is but one exception in the tables appended to the author's work, already alluded to, viz., Fort Crawford, but the results of this post are based on only two years' observations. Fort Howard, it is seen, has in April a somewhat lower mean than that of the year, which, as it differs from the rest in this respect in consequence of having its temperature *partially* modified by the waters of Green Bay, is an exception which confirms the rule. At the posts in the modified climates, the mean temperature of April, with the single exception of Fort Sullivan, is generally as much lower as that of October is higher, than the annual mean. This law is beautifully illustrated in the results obtained at Salem, based on thirty-three years' observations, the mean of April being 2°.50 lower, and that of October 2°.54 higher, than the annual mean. Fort Vancouver, which is not situated near a large body of water, derives its uniform climate from its position near the western coast of the continent.

A decision of this long-mooted question is thus presented, illustrating the ancient axiom that truth is never found in extremes. Kirwan, however, was somewhat nearer the truth than Humboldt. As regards any credit that may pertain to this explanation—a deduction which the author made several years ago—he considers it exclusively his own.

There are of course two periods of the year when an equality with the annual temperature occurs. It has been ascertained by thermometers placed at different depths, from one to eight feet, that there exists a regular current of heat into the earth during the summer, as long as the mean temperature of the atmosphere is more elevated than that of the interior; and, on the contrary, that this current, during the winter, directs itself toward the surface to compensate the want of heat produced by the exterior cold. Thus, at a certain depth, an equilibrium of temperature is gradually established twice a year, that is, at the periods referred to in the preceding paragraph, perhaps generally in April and October.

The movements of temperature, in accordance with the seasons, from the surface of the ground to the invariable stratum, have been already brought under notice. A series of observations extending through the period of a year, consisting in noting the temperature of the earth at the depth of thirty inches, was conducted by the author, on Bedloe's Island, in the harbor of New York. They were made in a loose sandy soil, in which the thermometer, at each observation, was kept buried about two hours. In the summer, it was found that the mean temperature of the earth is lower than that of the superincumbent atmosphere, and that in winter it is higher; while at two periods in the year, about April and October, there is an equilibrium. Taking the mean of these subterranean observations for the year, it was ascertained that the result was the same as that given by the usual thermometrical observations made in the atmosphere. In the summer months, the variations of the temperature beneath the surface, judging from observations made in the morning, at noon, and in the evening, seem to be as great as in the atmosphere; but as the former are uninfluenced by every change of wind, they are of course not so fluctuating during the twenty-four hours. In dry summer weather, there is little difference between the ground and atmosphere; but just after a rain, as the sandy soil becomes saturated with moisture, an observation beneath the surface at noon shows a temperature five degrees lower than that of the atmosphere. The surface of the earth to the depth of perhaps an inch has always a temperature very different from that of the air, being much higher during the day, and much lower during the night.

From the general survey of the laws of climate, as illustrated in the preceding pages, we cannot fail to observe in a department of creation in which the designs of Providence have been regarded as most obscure, the harmonious results of operations apparently the most conflicting. The causes of climate constitute together a circle, of which we can designate neither the first nor the last concatenation. The general evaporation of water, and its subsequent condensation, for example, play an important part in regulating the temperature of climates. Tropical countries, by the cold produced in the formation of vapor, are rendered habitable; while the latent heat given out to the ambient medium, as the vapor becomes condensed and descends in rain over the temperate and frigid zones, meliorates their rigor.

Much still remains unsaid in regard to several of the causes enumerated in the early part of this chapter, as being chiefly influential in modifying climate on the same parallels. The importance of clouds in the economy of nature has been already noticed. As they greatly mitigate the extremes of temperature, we thus discover, in addition to the reasons already assigned, another cause of the modified temperature of positions on large bodies of water; for, as the sky is more subject to be overcast by clouds than in the opposite localities, the radiation of heat to the heavens at night will be correspondently diminished.

The agency of snow in affording protection to vegetable substances on the surface of the earth, may be explained in the same way. Instead of acting merely as a shield against the cold of the atmosphere, it obviates the occurrence of the low temperature which bodies on the surface of the earth acquire, during still and clear nights, by the radiation of their heat to the heavens. Although a thick covering of snow causes the surface of the earth to be warmer; yet, as the radiation and conduction of heat from the ground are prevented, a greater degree of cold must necessarily occur in the lower atmosphere.

Climate is influenced also by the chemical and geological character of the earth. One soil quickly parts with its acquired heat, while another retains it tenaciously. The temperature of regions whose surface is covered with sand, is higher than that of those in which it consists of clay or some other compact earth; and rocky soils and barren deserts are much warmer in summer than countries covered with vegetation on the same parallels.

Currents in the ocean and the accumulation of ice which drifts into comparatively low latitudes, tend, likewise, to produce an unequal distribution of heat. The oceanic current, which flows by the eastern coast of North America, is a cold polar stream, sweeping immense masses of ice into lower latitudes, thus cooling the surrounding seas, and giving to the winds which blow from them a harsh and chilling influence. The effects of this as well as the gulf-stream upon the climate of the United States, have been pointed out already.

The influence of currents of air, by mixing the temperature of different localties, in modifying climate and causing variation of weather, is well known. The direction, the intensity, and the nature of winds, as already observed, depend, without reference to the polar and equatorial currents, upon local and general exposure, the vicinity of seas, the elevation and relative position of mountains, and other circumstances. Localities having a southern exposure, will have a much higher temperature than places lying north or to the windward of a chain of mountains. As regards the effects of winds on the temperature of a place, there is a great difference between the lower and the higher latitudes. In the former, a change of wind rarely raises or depresses the thermometer more than a few degrees; while in the higher latitudes, it frequently happens that in several hours a change of 10° or 12°, and even more, takes place. Captain Scoresby mentions an in-

stance near the polar ice, in which the mercury fell in sixteen hours 34° namely from ×32 to—2°; and in our northern States, intense cold is felt, when the winds blow from the frozen regions around Hudson's Bay. But it has already been stated, on the strength of the British army statistics, that at Quebec the mercury has been known to fall 70° in the course of twelve hours; and we may add that, at New York, in August, 1809, according to the observation of Dr. John W. Francis, the thermometer, upon the sudden coming on of a north-west storm of rain, evinced a difference of 40° within one hour. From snow-clad mountains, gusts of cold air, called snow-winds, rush down and cool the adjacent plains, while currents of air traversing extensive deserts of burning sand, as in Africa, accumulate an astonishing degree of heat, even, it is said, to the boiling point.

Thus temperature, as just remarked, is greatly influenced by general and local aspects; but these, at the same time, should be distinguished, for the general declivity of a country does not preclude the most opposite local declivities. In the northern hemisphere, according to Malte-Brun, the *south-west* and the *south-south-west* situations are the warmest of all; while those of the *north-east*, on the contrary, are the coldest. This remark was intended of course to apply to Europe, as the *north-east* winds with them traverse a cold continent; but, with us, the *north-west* winds, it must be borne in mind, stand in the same relation. The influence of the exposure of a soil relatively to the sun is very apparent, if we consider that a hill inclined 45° to the south, when the sun is elevated 45°, receives its rays perpendicularly, while the same rays strike the soil of a plain under an angle of 45°, that is, with one quarter less of force. On the other hand, a hill inclined 45° to the north will be struck by the solar rays in a horizontal direction, causing them to glide along its surface.

The positions of mountains act on climate in two ways. They not only attract the vapor suspended in the air, which by its condensation, produces clouds and fogs; but they often stop in their devious course, these assemblages of watery substances, which are wafted by the winds in every direction. When crowned with extensive forests, these effects are produced in the most striking degree.

Mountains do not play a more important part in Geology, than they do in reference to the agriculture of countries even far distant from them. They give origin to all rivers; as the course of the winds is determined by them, so is also the fall of the fertilizing rains; and they form mighty bulwarks, causing remarkable modifications of climate. "A valley which is open to the south," in the language of the *Maison Rustique du XIX Siècle*, "acquires a much greater degree of heat than the plains and the mountains of the same climate which have not such an exposure, in general very advantageous in our temperate latitudes. These valleys are especially remarked among the Cevennes and the maritime Alps, upon the limits of the cultivation of the olive and fig trees. The valleys which have their opening toward the north, present the contrary effect; the vine cannot be profitably cultivated in them in the climate of Paris or even farther south. The valleys exposed to the sunrise enjoy a part of the heat of the day; those which are exposed to the setting sun, scarcely receiving any, will be little warmer than those exposed to the north; but as in a great part of France the winds from the east are very cold, and those from the west tolerably warm, these two latter exposures, with some modifications, will be nearly equal in temperature. * * The mountains are the most powerful of natural shelters. Rozier cites, in regard to the climate of France, a striking example of their influence upon culture. If we draw a line from Nice in Piedmont to St. Sebastian in Spain, in traversing the most southern provinces of France, we find four well distinguished climates. The first is the country of oranges, olives and vines; it has to the south the Mediterranean and the burning climates of Africa, and immediately behind it the Alps, cultivated almost to the peak, which shelter from the north. The second from Toulon, the country of olive trees and vines, without oranges. It has the sea toward the south still, but the mountains which shelter it are at a distance from the coast. The third from Circassonne is the country of the vine without either oranges or olives: it has in fact the Pyrenees to the south. The fourth is from Bayonne, the country destitute of vines, has the Pyrenees to the south, and they are so near that they shelter it completely from all the southern winds: apples are raised there as in Normandy and Brittany, and yet this country is further south than Grasse and Nice. In studying thus, throughout the kingdom, the influence of natural shelters, we shall often discover the cause determining the culture of each country, still, however, in subordination to the nature of the soil. We shall therefore be on our guard against systems of culture embracing the entire kingdom; and before introducing new crops on his estate, the cultivator will require the favorable influences which act upon the locality which he inhabits. Improve the methods and crops of your district, but never change them entirely without first making experiments."

As temperature decreases progressively with the elevation of land, great varieties of vegetation are presented in the same region. While the flowers of spring are unfolding their petals on the plains of Northern France, winter continues his icy reign upon the Alps and Pyrenees. By this beneficent appointment of Nature, the torrid zone presents many habitable climates. On the great table-plain of Mexico and Gautemala, a tropical is converted into a temperate clime. As the vernal valley of Quito lies in the same latitude as the destructive coasts of French Guiana, so the interior of Africa may possess many localities gifted with the same advantages. "In ascending from Bengal to Thibet,," says Malte-Brun, "we imagine ourselves in a few days transported from the equator to the poles." And climbing Mount Ararat, according to Tournefort, we observe at its foot the plants of Western Asia; a little higher up, the vegetable forms of Italy are recognized; next, those of Central France; at a still higher level, those of Sweden; and beyond this last point, the flora of Lapland and the Alps. In our own country, reference has already been made to the marked contrast between the Atlantic plain and the parallel ridges; but it is in the geographical features of Columbia, in South America, that we find most strikingly displayed the physical phenomena of *height* producing the effect of *latitude*—a change of climate with all the consequent revolutions of animal and vegetable life, induced by local position. It is on the mountain slopes of 3000 to 7000 feet, beyond the influence of the noxious miasmata, that man dwells in perpetual summer amid the richest vegetable productions of nature. In the mountains of Jamaica, at the height of 4,200 feet, the vegetation of the tropics gives place to that of temperate regions; and here, while thousands are cut off annually along the coasts by yellow fever, a complete exemption exists. In the elevated regions, the inhabitants exhibit the ruddy glow of health which tinges the countenance in northern climes, forming a striking contrast to the pallid and sickly aspect of those that dwell below. In ascending a lofty mountain of the torrid zone, the greatest variety in vegetation is displayed. At its foot, under the burning sun, ananas and plantains flourish; the region of limes and oranges succeeds; then follow fields of maize and luxuriant wheat; and still higher, the series of plants known in the temperate zone. The mountains of temperate regions exhibit perhaps less variety, but the change is equally striking. In the ascent of the Alps, having once passed the vine-clad belt, we traverse in succession those of oaks, sweet chestnuts, beeches, till we gain the region of the more hardy pines and stunted birches. Beyond the elevation of 6,000 feet no tree appears. Immense tracts are then covered with herbaceous vegetation, the variety in which ultimately dwindles down to mosses and lichens, which struggle up to the barrier of eternal snow. In the United States proper we have at least two summits, the rocky pinnacles of which shoot up into the sky to the altitude perhaps of 6,500 feet. Of these, Mount Washington, in New Hampshire, is one. Encircling the base is a heavy forest—then succeeds a belt of stunted firs: next a growth of low bushes: and still further up only moss or lichens, or lastly a naked surface, the summits of which are covered, during ten months of the year, with snow. Of the snow-capt peaks of Oregon, we possess no precise knowledge.

"The admirable order," says Humboldt, "with which different tribes of vegetables rise above another by strata, as it were, is nowhere more perceptible than in ascending from the port of Vera Cruz to the table-land of Perote. We see there the physiognomy of the country, the aspect of the sky, the form of plants, the figures of animals, the manners of the inhabitants, and the kind of cultivation followed by them, assume a different appearance at every step of our progress.

"As we ascend, nature appears gradually less animated, the beauty of the vegetable forms diminishes, the shoots become less succulent, and the flowers less colored. The sight of the Mexican oaks quiets the alarms of a traveller newly landed at Vera Cruz. Its presence demonstrates to him that he has left behind him the zone so justly dreaded by people of the north, under which the yellow fever exercises its ravages in New Spain.

"This inferior limit of oaks warns the colonist who inhabits the central table-land, how far he may descend toward the coast without dread of the mortal disease of the *vomito*. Forests of liquid-amber near Xalapa, announce by the freshness of their verdure, that this is the elevation at which the clouds suspended over the ocean, come in contact with the balsatic summits of the Cordillera. A little higher, near La Banderilla, the nutritive fruit of the banana tree comes no longer to maturity. In this foggy and cold region, therefore, want spurs on the Indian to labor, and excites his industry. At the height of San Miguel, pines begin to mingle with the oaks, which are found by the traveller as high as the elevated plains of Perote, where he beholds the delightful aspect of fields sown with wheat. Eight hundred metres higher, the coldness of the climate will no longer admit of the vegetation of the oaks; and pines alone there cover the rocks, whose summits enter the zone of eternal snow. Thus, in a few hours, the naturalist, in this miraculous country, ascends the whole scale of vegetation, from the heliconia and banana plant, whose glossy leaves swell out into extraordinary dimensions, to the stunted parenchyma of the resinous trees."

Here, indeed, is evidenced the effect of elevation as equivalent to latitude; for the Creoles, who inhabit the elevated table-land, where the mean temperature is about 60°, and the thermometer sometimes sinks below the freezing point, suffer, when they descend the eastern declivity of the Cordillera, being thus plunged at once into the hot and deleterious atmosphere of Vera Cruz, even more than European strangers who approach it gradually by sea.

Reference may here be made to the "*well-established fact of meridians of greatest cold*," so called by Traill in the Encyclopædia Britannica. "The remarkable fact," he says, "of the influence of *longitude* on temperature leads to the conclusion, that on each side of the equator there are two meridians, under which the mean temperature is lowest. These have been termed by Sir David Brewster the *cold meridians*, and their extremities are the *poles of greatest cold*. The position of these in the northern hemisphere may be approximated from recent investigations; and perhaps we shall not greatly err if we assign the longitude of 95° W. for the American, and of 100° E. for the Asiatic cold meridians. The apparent coincidence of the cold meridians with the general directions of Hansteen's lines of no variation is perhaps more than accidental, when we reflect that there seem to have been, in former ages, migrations of the cold meridians eastward and westward, coincident, as far as we can judge from recorded changes of climate in northern countries, with similar migrations of the magnetic needle."

This theory of cold meridians is at best extremely problematical. If there is any truth in the laws of climate as based on physical geography, then is this theory no more than the "baseless fabric of a vision." It is true that the meridians selected are the coldest in some latitudes of the northern hemisphere, inasmuch as they traverse the interior of the continents, considerably nearer the eastern or colder side. The longitude of 95° W., for instance, passes nearly two degrees west of Fort Snelling, Iowa, which is very probably the coldest meridian in the United States; but as this same meridian passes through the Gulf of Mexico, the result there at once explodes the whole hypothesis. And as the same meridian continued into the southern hemisphere, traverses the Pacific Ocean, the theory is again at fault; for the laws of climate resulting from physical geography place it about 30° farther east on the continent of South America; and in the Old World, the coldest meridian, if continued into the southern hemisphere, instead of being that of 100°, will be found either in Africa or New Holland. But the circumstance of the migration of these meridians, makes still greater demands upon our credulity, inasmuch as it runs directly counter to the well-established principle that any alteration in the climate of a locality supposes a corresponding alteration in its physical features. That there are *poles of greatest cold* corresponding to the terrestrial magnetic poles, as distinguished from the poles of rotation, is, however, quite probable.

In regard to the position of the *magnetic* pole, the following remarks

are made by Lieutenant Wilkes, in his "Synopsis of the Cruize of the United States Exploring Expedition." "I consider that we have approached very near the pole. Our dip was 87° 30′ south, and the compasses on the ice very sluggish: this was in 147° 30′ east and 67° 4′ south. Our variation as accurately as it could be observed on the ice, we made 12° 30′ east. It was difficult to get a good observation, on account of the sluggishness of our compasses. About 100 miles to the westward we crossed the magnetic meridian. The pole, without giving you accurate deductions, I think my observations will place in about 70° south latitude and 140° east longitude."

SECTION IV.

The following subjects yet remain to be considered: 1. Does the climate of a locality in a series of years, undergo any permanent changes? 2. Does the climate of our North-western frontier resemble that of the Eastern States on their first settlement? 3. Is the climate west of the Alleghanies milder by 3° of latitude than that east?

SUBSECTION 1. DOES THE CLIMATE OF A LOCALITY, IN A SERIES OF YEARS. UNDERGO ANY PERMANENT CHANGES?—Astronomical observations prove that the temperature of the earth has not, during the last 2,000 years, increased or decreased a single degree.—In reference to the question, whether the climate of Europe was more austere 2,000 years ago than now, the writings of Diodorus Siculus, Juvenal, Virgil, Ovid, and Gibbon quoted in the affirmative.—On the negative side, a multiplicity of facts adduced, showing that, since the days of Julius Cæsar, the melioration of climate is slight indeed, being limited, perhaps, to the less frequent occurrence of severe seasons.

The question has been much debated, whether the temperature of the crust of the earth or of the incumbent atmosphere, has undergone any perceptible changes since the earliest records, either from the efforts of man in clearing away forests, draining marshes, and cultivating the ground, or from other causes. As the earth is continually receiving heat from the sun, it follows that, if no caloric is thrown off into surrounding space, its mean temperature must be continually augmenting. It has accordingly been inferred that the increase of temperature is at the rate of 1° in eighty years; and thus the changes of climate alleged to have gradually supervened during successive ages in many countries, and particularly in the west of Europe, are attempted to be explained. But many geologists, on the other hand, maintain the doctrine, (on the supposition that the surface of the earth had a higher temperature at the period of the formation of the older rocks,) of a decreasing superficial temperature as the result of radiation. It has been satisfactorily demonstrated by La Place, however, that since the days of Hipparchus, an astronomer of the Alexandrian school, who flourished about 2000 years ago, the temperature of the earth cannot have increased or decreased a single degree, as otherwise the siderial day must have become either lengthened or shortened, which is not the case.

The precise results of astronomical observations prove that, as any change in the temperature of our globe would be attended by a corresponding mutation of volume, an alteration in the momentum of the revolving mass would follow. Were the earth, for instance, to gain, from the accession of heat, only a millionth part of linear expansion, it would require, to maintain the same rotation, an increase of five times proportionally more momentum. The diurnal revolution would, therefore, on this supposition, be retarded at the rate of three seconds in a week. But as the length of the day has certainly not varied one second in a year since the age of Hipparchus, it follows that, in the lapse of 2000 years, the mass of our globe has not acquired the increased expansion due to the smallest fraction of a degree of heat. On the other hand, were there a progressive accumulation of ice on the surface of our Polar seas, a prolongation of the length of the day would be occasioned.

A question asked by the learned M. Arago, in his instructions to the officers of the exploring ship, *La Bonite*, is—Has the earth, in regard to its temperature, arrived at a permanent state? The solution of this question, he says, seems to require only a direct comparison between the mean temperatures of the same place, taken at two remote periods. But in reflecting upon the effect of local circumstances—in seeing to what a degree the vicinity of a lake, a forest, a mountain naked or wooded, a plain sandy or covered with grass, will modify temperature, it is apparent that thermometrical data alone will not suffice, unless we can be assured that between the two periods, this tract of land, and even the surrounding country, have not, either in their aspect or mode of culture, undergone any material change. This, as is seen, complicates the question very much; for, with positive data, susceptible of exact appreciation, there become mixed up collateral circumstances before which the philosophic mind rests in suspense. M. Arago, therefore, suggests another mode, which is free from complication. This consists in observing the temperature in the open sea, remote from continents. Were such meteorological data bequeathed from age to age, the question would admit of solution.

In regard to the former and present temperature of the earth, M. Arago arrives at the conclusion that in Europe in general, and in France in particular, the winters were, in former ages, at least as cold as at present—an opinion founded upon the alleged fact of the congelation of rivers and seas at a very ancient period. He thinks that the conquests of agriculture, such as the opening of forests and the draining of marshes, as well as the confinement of water courses to their channels, have caused a sensible elevation of the mean annual temperature. But, after all, M. Arago looks to America for the data necessary to settle this point definitely.

"Ancient France," he remarks, "contrasted with what France now is, presented an incomparably greater extent of forests; mountains almost entirely covered with wood, lakes, ponds, and morasses, without number; rivers without any artificial embankment to prevent their overflow, and immense districts which the hands of the husbandman had never touched. Accordingly, the clearing away of the vast forests, and the opening of extensive glades in those that remain; the nearly complete removal of all stagnant waters, and the cultivation of extensive plains, which thus are made to resemble the *steppes* of Asia and America—these are among the principal modifications to which the fair face of France has been subjected, in an interval of some hundreds of years. But there is another country which is undergoing these same modifications at the present day. They are there progressing under the observation of an enlightened population; they are advancing with astonishing rapidity; and they ought, in some degree, suddenly to produce the meteorological alterations which many ages have scarcely rendered apparent in our old continent. This country is North America. Let us see, then, how clearing the country affects the climate there. The results may evidently be applied to the ancient condition of our own countries, and we shall find that we may thus dispense with *a priori* considerations, which, in a subject so complicated, would probably have misled us."

The winters of the south of Europe, in the time of the first Roman Emperors, were, according to the concurring testimony of many authors, much more severe than now. That the rivers of Gaul and Germany were always frozen during winter, is mentioned by Diodorus Siculus. Juvenal, in recording the ceremony of a superstitious rite performed by a female, refers to the necessity of breaking the ice of the Tiber:

> Hybernum fracta glacie descendet in amnem
> Ter matutino Tiberi mergetur.—*Sat.* vi., *line* 521.

Virgil recommends great attention to young sheep, lest the cold should destroy them:

> ——Glacies ne frigida lædat
> Molle pecus.—*Geo., lib. iij., l.* 298.

Again, Ovid, in lamenting, in pathetic strains, his banishment, takes notice of the freezing of the Euxine, and of the congelation of wine in its vicinity:

> Ipse vides certe glacie concrescere Pontum;
> Ipse vides rigido stantia vina gelu.—*Ex Ponto, lib.* iv., *Epist.* 7.

The instance cited from Ovid may as well be disposed of at once. Lying, as Constantinople does, nearly in the same latitude as Naples, and situated on the shore of the sea of Marmora and the banks of the Bosphorus, close to the Black Sea and at no considerable distance from the Mediterranean, it might be expected, at first view, that its climate would not differ much from that of Southern Italy. When we consider, however, that Europe is separated from the polar circle by an ocean, and is intersected by seas which temper the climate, moderating alike the excess of heat and cold, while Africa, like an immense furnace, distributes its heat toward the same region, its climate must surely be more mild and uniform than that of Constantinople, which has on its east and north an immense continent, both elevated and extending toward the poles—causes which produce the extremes of atmospheric temperature. "The circumstances most peculiar in the character of its climate," [Constantinople] says Dr. John Davy, "are irregularity—variability, the sudden changes of temperature, with changes of wind and weather to which it is liable, and the wide range of the thermometer. * * * A fall of snow is not considered remarkable in April; a shower of snow has suddenly masked the bright verdure of the early May; even in summer, the most equable season, the range of the thermometer is considerable, and the fluctuations of temperature are often great. In July last [1841] it was often so low as 70° before sunrise, and as high as 90°, or above that, in the afternoon in the shade." While the variation of temperature of the Mediterranean, through the greater part of the year, very seldom exhibits a greater range than from 55° to 82°, at Constantinople, during two years' observations, the range extended from 24° to 91°.

Upon this subject, Gibbon, in his "Decline and Fall of the Roman Empire," makes the following remarks:

"Some ingenious writers* have suspected that Europe was much colder formerly than at present; and the most ancient descriptions of the climate of Germany tend exceedingly to confirm this theory. The general complaints of intense frost and eternal winter, are perhaps little to be regarded, since we have no method of reducing to the accurate standard of the thermometer, the feelings, or the expressions, of an orator born in the happier regions of Greece or Asia. But I shall select two remarkable circumstances of a less equivocal nature. 1. The great rivers which cover the Roman Provinces, the Rhine and the Danube, were frequently frozen over, and capable of supporting the most enormous weights. The barbarians, who often chose that severe season for their inroads, transported, without apprehension or danger, their numerous armies, their cavalry, and their heavy wagons, over a vast and solid bridge of ice.† Modern ages have not presented an instance of a like phenomenon. The rein-deer, that useful animal, from which the savage of the north derives the best comforts of his dreary life, is of a constitution that supports, and even requires, the most intense cold. He is found on the rock of Spitzberg, within ten degrees of the pole; he seems to delight in the snows of Lapland and Siberia; but at present he cannot subsist, much less multiply, in any country to the south of the Baltic.‡ In the time of Cæsar, the rein-deer, as well as the elk and the wild-bull, was a native of the Hercynian forest, which then overshadowed a great part of Germany and Poland.‖ The modern improvements sufficiently explain the causes of the diminution of the cold. These immense woods have been gradually cleared, which intercepted from the earth the rays of the sun.§ The morasses have been drained, and, in proportion as the soil has been cultivated, the air has become more temperate. Canada, at this day, is an exact picture of ancient Germany. Although situated in the same parallel with the finest provinces of France and England, that country experiences the most rigorous cold. The rein-deer are very numerous, the ground is covered with deep and lasting snow, and the great river of St. Lawrence is regularly

* In particular, Mr. Hume, the Abbe du Bos, and M. Pellontier.—*Hist. des Celtes, tom.* i.

† *Diodorus Siculus, l.* v., *p.* 340. *Edit. Wessel. Herodian, l.* vi., *p.* 221. *Iornandes, c.* 55. On the banks of the Danube, the wine, when brought to table, was frequently frozen into great lumps, *frustra vini.* Ovid, *Epist. ex Ponto, l.* iv., 7, 9, 10. Virgil, *Georgic, l.* iij. 355. The fact is confirmed by a soldier and a philosopher, who had experienced the intense cold of Thrace. See *Xenopon, Anabasis, l,* vij., *p.* 560. *Edit. Hutchinson.*

‡ *Buffon, Histoire Naturelle, tom.* xij., *p.* 79, 116.

‖ *Cæsar de Bell., Gallic* vi. 23, *etc.* The most inquisitive of the Germans were ignorant of its utmost limits, although some of them had travelled it more than sixty days' journey.

§ Cluverius, (*Germania Antiqua, l.* iii., *c.* 47,) investigates the small and scattered remains of the Hercynian wood.

frozen, in a season when the waters of the Seine and the Thames are usually free from ice."

This quotation is made, not because it quadrates with the author's views, but as expressive of the general sentiment on the subject. In the first place, it may be remarked that Gibbon was ignorant of the great laws of climate, or he would not have said that "*Canada, at this day, is an exact picture of ancient Germany;*" but this is the less surprising when it is known that Malte-Brun, many years after, made the same comparison. But more of this anon. Gibbon, indeed, is excusable, inasmuch as he lived before the epoch of Baron Humboldt. Gibbon's reputation is that of a *historian;* but it will be easy to show that he falls short even in this character, as regards the assertion, when speaking of transporting heavy waggons over the frozen rivers of ancient Germany, that "*modern ages have not presented an instance of a like phenomenon.*"

As much importance has been attached to classic records by many, with the view to establish the opinion that the climate of Europe, two thousand years ago, was *much more* rigorous than now, the author has been at some pains to collect historical facts enough to show this conclusion to be unwarranted—a conclusion, moreover, which is adverse to the deductions authorized by the laws of climate established by these researches. As we have no exact instrumental observations of temperature that go back much farther than a century, our information in regard to more remote periods being derived from loose notices scattered through the old chronicles, relative to the state of the harvest, the quality of the vintage, or the endurance of frost and snow in the winter, great allowance must be made for the spirit of exaggeration which tinges all rude historical monuments. The facts stated by the Roman poets, if not exaggerated, doubtless, in many instances, stand isolated, not unlike the fact recorded in relation to the Baltic, which, in 1688, was so firmly frozen that Charles XI. of Sweden crossed it with his army, or the similar circumstance that in the winter of 1779–80, horse and artillery were transported over the ice in the harbor of New York. It appears, indeed, from historical evidence, that the most remarkable extremes of heat and cold have been frequently recurring ever since the time of the Romans referred to above, the opinion of Gibbon to the contrary notwithstanding. A few striking examples will be here adduced, though ten times the number might be as readily presented*:—In A. D. 401, the Black Sea was entirely frozen over. In 763, the same occurred both in regard to the Black Sea and the Straits of Dardanelles. In some places the snow rose fifty feet in height, and the ice was so heaped up in the cities as to push down the walls. In 1133, the Po was frozen from Cremona to the sea In many parts of Italy, the roads were rendered impassable by the heaps of snow; and by the action of the frost, wine-casks burst in the cellars, and even trees split with immense noise. In 1234, the Po was again so firmly frozen, that loaded wagons crossed the Adriatic to Venice; and at Ravenna, a pine forest was killed by the frost. In 1408, not only was the Danube frozen over, but also the sea between Gothland and Zeland, and between Norway and Denmark; and in France, the vineyards and orchards were destroyed. In both 1468 and 1544, the winter in Flanders was so severe, that the wine distributed to the soldiers was cut into pieces with a hatchet. In 1571, all the rivers in France were covered with solid ice, and the fruit-trees, even in Languedoc, perished. In 1621–2, the rivers of Europe were mostly frozen, and even the Zuyder Zee. The Hellespont was covered with a sheet of ice, and the Venetian fleet became blocked up in the lagoons of the Adriatic. The winters of 1658, '59 and '60, were intensely cold throughout Europe. In Italy, the rivers bore heavy carriages, and so much snow had not fallen at Rome for several centuries. It was in 1658 that Charles X. of Sweden crossed the Little Belt over the ice, from Holstein to Denmark, with his whole army, horse and foot, with a train of baggage and artillery. In 1670, the cold was most intense in England and Denmark; both the Little and Great Belt were frozen. Again in 1684, in England, many forest trees, and even oaks, were split by the intensity of the frosts. In 1709 occurred what has been called by distinction, "the cold winter." In Europe, all the rivers and lakes, and even the seas to the distance of several miles from the shore, were frozen. It is said that the ground was penetrated by the frost to the depth of three yards. The more tender vegetation in England was killed, and wheat rose in price from two to four pounds a quarter. In the south of France, the olive plantations were almost all destroyed. The Adriatic was quite frozen over, and even the coasts of the Mediterranean about Genoa; and in the mildest parts of Italy, the citron and orange trees suffered severely. In 1740, the cold was scarcely less intense than in 1709. In Spain and Portugal, the snow lay eight or ten feet deep. The Zuyder Zee was frozen over, and many thousand persons walked or skated on it. At Leyden, the thermometer fell 10° below the zero of Fahrenheit's scale. All the lakes in England were covered with ice; a whole ox was roasted on the Thames; many trees were killed by the frost, and postillions were benumbed on their saddles. In both the years 1709 and 1740, the General Assembly of the Church of Scotland, on account of the dearth which then prevailed, ordained a national fast to be held.

These examples might be multiplied tenfold and continued up to the present day, were it necessary in order to disprove the gratuitous assertion of Gibbon, that "modern ages have not presented an instance of a like phenomenon." At the same time, it will not be without advantage to bring under notice a similar series of facts extracted from the work of Noah Webster, which has already furnished many interesting facts illustrative of the climate of the United States during our earlier history. Dr. Webster, in every instance, quotes his authority, which is here deemed unnecessary. He often refers to winters as being extraordinarily *cold, severe, rigorous;* but, in no case, has the author made a quotation, unless the precise effects of the weather were stated.

In the year of our Lord 400, there occurred one of the most severe winters on record, the Euxine sea being covered with ice for twenty days. In 717, the Saracens marching, in an immense army, to besiege Constantinople, perished with *cold*, hunger, and pestilence. In 823, snow lay on the ground for twenty-nine weeks, occasioning the death of many men and brutes. In 858, the Adriatic sea was covered with ice, and people walked on it to Venice. In 929, the Thames was a solid bridge of ice for thirteen weeks. In 1063, there were deep snow and extreme cold, proving fatal to vines, trees, birds, and cattle. In 1076, it was excessively cold from November to March, the roots of vines being killed. In 1124, trees and vines were destroyed. In 1263 and 1269, the Thames became a highway for men and horses. In 1402, the Baltic was passable for horses and carriages for six weeks. In 1609, the Thames again a common highway. In the winter of 1654–5, the rivers and harbors of Holland were all locked up by congelation. In the winter of 1664–5, the Thames became once more a bridge of ice. The winter of 1708–9 was very severe both in Europe and America, destroying vines and fruit-trees. In 1716, a fair was held on the Thames. In January 1729, the rivers and canals in Holland were covered with ice of the thickness of 12–20 inches. The winter of 1739–40 was the severest known in Europe since that of 1708–9. It preceded by one year, as previously remarked, a very cold winter in America—a circumstance which, from its frequent recurrence, seems to be more than a mere coincidence. In the winter of 1756–7, in Syria, fruit-trees were destroyed, and also olive-trees which had withstood the climate for fifty years, and thousands of poor people perished with cold. In the winter of 1762–3, the Thames was again a highway for carriages, and the poor perished in the streets of London. In the winter of 1765–6, at Ratisbon, the mercury was 2° lower than in the noted year of 1709, and birds perished with cold. At Naples, the snow lay in the streets to the depth of eighteen inches. At Lisbon, the thermometer was 3½° below the freezing point; and at Madrid, people skated on the ice. In the winter of 1766–7, "the Rhine at Cologne became a bridge of ice, and supported laboring artificers, as in 1670. In Italy, the poor crowded to the cities for aid, and perished with cold. In Russia, both rich and poor perished. The wolves became ravenous, entered towns and destroyed people. In England, the larks took refuge in hay-carts and the market; the snow fell to the depth of many feet and buried thousands of sheep." In America, similar phenomena, as already described, were witnessed. In the winter of 1767–8, the cold in France was more severe than in 1740, and within a degree of the low temperature of 1709. In Constantinople, snow fell as late as the 16th of March. The winter of 1779–80, so remarkable in the United States, was as severe comparatively in Europe. The winter of 1783–4 was also an extraordinarily rigorous one in the United States, as described before. "In Europe," says Dr. Webster, "it was no less severe—an instance in which a severely cold winter in Europe coincided in time, with the same in America. It may be remarked also that this winter was just one century after the coincidence of like events; the winter of 1683–4 being equally severe in both hemispheres. In 1783–4, the river Liffey, in Ireland, the Thames in England, and all the rivers in the interior of Holland, were covered with solid ice. In Holland, the ice gave way about the first of March, and the rivers being greatly swelled, the adjacent country was inundated, with immense loss of lives and property. The river Woal, near Nimeguen, broke through its dikes, and overwhelmed thirty-four villages. The Rhine from Cologne and Manheim, exhibited similar scenes of devastation." The winter of 1788–9, in Europe, appears to have been unusually severe. The frost penetrated to the southern parts of Spain and Portugal; and the rivers in Estremadura and Alantejo were covered with ice. The winter of 1794–5 was likewise very cold. In January, the French troops marched into Amsterdam, over the rivers and canals, on the ice. This series of interesting facts, as previously observed, is brought down no farther than the year 1799.

In regard to high summer heats, during the same period, a similar series of facts might be presented. In one year, the springs dried up; in another, the reapers dropped dead in the field; in a third eggs were roasted in the sand: again, the heat and drought were so great, that not only were the springs dried up, but the Rhine and Danube exposed their dry beds.

By those that maintain that climates have become more uniform, it is stated, on the contrary, that Pliny, the younger, had a country-seat in Tuscany, where he could not raise olives, myrtles, and similar plants, which now attain the greatest perfection. Cæsar, when he invaded Britain, found the climate milder than that of Gaul. He mentions that corn did not come to maturity in the northern provinces of the latter, and that the inhabitants of the former went about unclothed. As an evidence of the views entertained of the climate of Britain, it may be stated that the Emperor Probus promulgated special instructions in regard to the planting of vines and the making of wine. The highest hills of Scotland, it is said, were formerly covered with trees, which, it is supposed by some, have disappeared in consequence of the diminished temperature of the climate. The culture of the vine, in the twelfth century, had attained such perfection in England, especially in the Vale of Gloster, that wine was made in abundance, and of an quality little inferior to that of France. The statistical records of Scotland show that wheat was formerly paid to religious institutions from lands on which the raising of that grain is now impracticable; and it appears that there was carried on, even during the sixteenth century, a considerable export trade in corn. That the vine was cultivated as a common plant in Scotland, is evident from the provident regulations passed in the reign of the earlier Jameses."*

It is thus seen that historical testimony in part neutralizes itself. One alleges that the climate of Europe has become more rigorous, asserting, by way of evidenee, that grain and fruit will no longer come to perfection in regions in which they formerly flourished and were perhaps indigenous; while another maintains the contrary, affirming that plants are now cultivated in the north of Italy, which formerly could not be preserved during the winter. Cultivation of the soil, so far from meliorating the climate of England and Scotland, has exerted, as may be inferred from the facts stated, an opposite tendency. In viewing the contradictory statements made in reference to these early periods, it must be borne in mind that the thermometer is a comparatively modern instrument, invented by the celebrated Sanctorio in 1590; but still left so imperfect, that it was not till the year 1724 that Fahrenheit succeeded in improving it sufficiently to warrant a comparison of observations. The want of exact instrumental observations prior to the com-

* These facts are taken from a volume published in London, in 1830, by Taylor, who says that he extracted them from the work of Offeffor of Germany, entitled "*The History of Climates and Changes,*" compiled from an old work published by Pilgram at Vienna, in 1788, combined with the observations made by Professor Pfaff of Keil.

* These historical facts are taken chiefly from a curious book by Foster on "Atmospheric Phenomena."

mencement of agricultural improvements, therefore, renders it impracticable to determine with any degree of precision, what changes may have been effected through these causes, in the mean annual temperature or in that of particular seasons.

It is not surprising that one should hear continual complaints of the altered condition of the seasons, especially from elderly persons, in whom the bodily frame has become more susceptible to the impressions of cold; but similar lamentations, like the prevalent notion that men in general were taller in the earlier ages of the world, have been repeated by the poets and the vulgar from time immemorial. That the vine will no longer thrive in many parts of England in which it formerly flourished, may be readily explained upon the ground of the *influence of situation upon agriculture*, as pointed out already. It is probable that the mere removal of extensive forests, which act as natural shelters to vegetation, may cause such a degree of exposure as to render the locality no longer suited to the culture of plants, to which it was previously well adapted. Besides, this same cause will have an influence upon the fall of the fertilizing rains. Moreover, it is not improbable that the vines grown in ancient times were coarser and more hardy plants than those now cultivated; for it is a well known fact that the character of the vegetable tribes is softened and rendered more delicate, by a succession of diligent cultures, while the flavor of the fruit is, at the same time, heightened. As wine was the accustomed beverage of the Roman soldiers stationed in Britain, it would naturally be supposed that they would prefer it, however poor and harsh, to the unpalatable ale brewed by the rude arts of the natives.

All observations then, thus far, confirm the belief in the general stability of climates. As regards the seasons, it will be shown, however, that in countries covered with dense forests, the winters are longer and more uniform than in dry, cultivated, regions, and that in summer, the mean temperature of the latter is higher. Hence, in regard to the opinion generally entertained, that the climate of Europe has been very much meliorated since the days of Julius Cæsar, it is clearly apparent, from the foregoing facts, that it is far from being sustained by evidence sufficient to enforce conviction. But, at the same time, while it is obvious that no material change has taken place, for the last 2000 years, in the climate of Europe, the conjecture that it has gradually acquired rather a milder character, or at least that its excessive severity seems on the whole to occur less frequently, appears to be warranted.

Although the mean temperatures, as has been ascertained by instrumental observations, vary from one another irregularly, either a few degrees above or below the *absolute* mean temperature of the place; yet it has not been found that the temperature of a locality undergoes changes in any ratio of progression. At the same time, this series of atmospheric changes, however complicated and perplexing, there is good reason to believe, is as determinate in its nature as the revolutions of the celestial bodies. When, however, the science of meteorology shall become more advanced, we shall doubtless discover that these apparent perturbations of annual temperatures are real oscillations—vast cycles, which will enable us to predict, no doubt with some degree of certainty, the condition of future seasons.

The period of these cycles are to us yet wholly unknown. Various conjectures on the subject have, however, been made. "The intermediate period of nine years, or the semi-revolution nearly of the lunar nodes and apogee, proposed by Toaldo, seems not to be altogether destitute of foundation. Thus, of the years remarkably cold, 1622 was succeeded, after the interval of four periods or 36 years, by 1658, whose severity lasted through the following years. The same interval brings us to 1695, and five periods more extend to 1740,—a very famous cold year; three periods now come down to 1767, nine years more to 1776, and eighteen years more to 1794, the cold continuing through 1795. Of the hot years it may be observed, that four periods of nine years extend from 1616 to 1652, and three such again to 1679. From 1701 to 1718 there was an interval of seventeen years, or very nearly two periods, while three periods reach to 1745, another period to 1754, and one more falls on 1763; and from 1779 to 1788, there are just nine years. The year 1818 would therefore correspond to 1701, 1719, and 1746, and consequently very nearly to 1718. Again, the years 1784, 1793, 1802, and 1811, at the intervals of successive periods, were all of them remarkably warm. A cycle of 54 years, including therefore six of these subordinate periods, has lately been proposed with much confidence, but apparently on slender grounds."—*Narrative of Discovery and Adventure in the Polar Seas and Regions. By Professor Leslie, Professor Jameson, and Hugh Murray, Esq. F. R. S. E.*

SUBSECTION 3.—DOES THE CLIMATE OF OUR NORTHWESTERN FRONTIER RESEMBLE THAT OF THE EASTERN STATES ON THEIR FIRST SETTLEMENT?—The affirmative maintained by Jefferson, Volney, Rush, and Williams.—Cultivation causes no change in the mean annual temperature, but the distribution of heat among the seasons may be so modified as greatly to influence vegetation.—Comparison of of thermometrical results, in our own country, at considerable intervals of time.—The supposition of Malte-Brun, that the climate of England, France, and Germany, twenty centuries ago, resembled the present condition of Canada and Chinese Tartary, unreasonable.—The region of Oregon in a state of nature even milder than highly cultivated Europe, while China, which has been under cultivation from time immemorial, is even more rigorous than the United States.

CHANGES of climate in the New World also are alleged to have supervened. This opinion is maintained by Jefferson, Volney, Rush, and Williams, the historian of Vermont. Mr. Jefferson, in his Notes on Virginia, makes the following observation:—"A change in our climate, however, is taking place very sensibly. Both heats and colds are becoming much more moderate within the memory of even the middle-aged. Snows are less frequent and less deep; they do not lie below the mountains more than one, two, or three days, and very rarely a week. They are remembered to have been formerly frequent, deep, and of long continuance. The elderly inform me that the earth used to be covered with snow about three months in every year. The rivers which seldom failed to freeze over in the course of the winter, scarcely ever do so now. This change has produced an unfortunate fluctuation between heat and cold in the spring of the year, which is very fatal to fruits."

Upon this subject, Dr. Rush remarks—"From the accounts which have been handed down to us by our ancestors, there is reason to believe that the climate of Pennsylvania has undergone a material change. * * * The springs are much colder, and the autumns more temperate, insomuch that cattle are not housed so soon by one month, as they were in former years * * * Rivers freeze later, and do not remain so long covered with ice."

By Williams, the historian of Vermont, the following observations are made:—"When our ancestors came to New England, the seasons and the weather were uniform and regular; the winter set in about the end of November, and continued till the middle of February. During this period, a cold, dry, and clear atmosphere prevailed, with little variation. Winter ended with the month of February: and when spring came, it came at once, without our sudden and repeated variations from cold to heat, and from heat to cold. The summer was suffocatingly hot; but it was confined to the space of six weeks. Autumn began with September, and the whole of the harvest was got in by the end of that month. The state of things is now very different in the part of New England inhabited since that time: the seasons are totally altered; the weather is infinitely more changeable; the winter is grown shorter, and interrupted by great and sudden thaws. Spring now offers us a perpetual fluctuation from cold to hot and from hot to cold, extremely injurious to vegetation: the heat of summer is less intense, but of longer continuance: autumn begins and ends later, and the harvest is not finished before the first week in November; in fine, winter does not display its severity before the end of December."

These opinions were quoted, more than forty years ago, by the celebrated Volney, in his "View of the Climate and Soil of the United States of America," to show that this climate, like that of Europe, grows more mild in proportion to the extent of cultivation. Now, admitting that such a change has occurred in the European climate, it were no easy matter to determine this question in respect to our own country by reference to these quotations. Instead of confirming, they may be just as aptly cited to disprove his position; for, it is remarked by Jefferson that the change "is very fatal to fruits," and by Williams, that it is "extremely injurious to all vegetation."

It has been further asserted, after the loose manner of the foregoing quotations, that on comparing the results of recent observations on our frontier with the best authenticated accounts we have of the climate of the Eastern states in their early settlement, a close similitude is found. The winters, it is said, have grown less cold and the summers less warm—consequences, which are ascribed to the clearing of the forest and the cultivation of the soil. That the climate of the great lakes resembles that of the sea-coast is very apparent; but that the region intermediate or the one beyond, ever maintained such a relation, is an assumption contrary to the laws of nature.

Dense forests and all growing vegetables, doubtless tend considerably to diminish the temperature of summer, by affording evaporation from the surface of their leaves, and preventing the calorific rays from reaching the ground. It is a fact equally well known that snow lies longer in forests than on plains, because, in the former locality, it is less exposed to the action of the sun; and hence, the winters, in former years, may have been longer and more uniform. As the clearing away of the forest, causes the waters to evaporate and the soil to become dry, some increase in the mean summer temperature, diametrically contrary to the opinion of Jefferson and others, necessarily follows. It is remarked by Umfreville that, at Hudson's Bay, the ground in open places thaws to the depth of four feet, and in the woods to the depth only of two. Moreover, it has been determined by thermometrical experiments that the temperature of the forest, at the distance of twelve inches below the surface of the earth, is, compared with an adjacent open field, at least 10° lower, during the summer months; while no difference is observable during the season of winter.

"The mere effect of cultivation," as Dr. Traill very correctly observes, "can never be very considerable in changing a climate;" but, although cultivation of the soil may not be productive of a sensible change in the mean annual temperature, yet such a modification in the distribution of heat among the seasons may be produced, as will greatly influence vegetation.

Although upon all subjects connected with natural phenomena, there is no higher authority than Charles Lyell, Esq., yet his unqualified decision of this question, as exhibited in the following quotation from his "Principles of Geology," is unsustained by any well observed facts:—"In the United States of North America, it is *unquestionable* that the rapid clearing of the country has rendered the winters less severe, and the summers *less* hot; in other words, the extreme temperatures of January and July have been observed from year to year, to approach nearer to each other. Whether in this case, or in France, the mean temperature has been raised, seems by no means as yet decided: but there is no doubt that the climate has become, as Buffon would have said, 'less excessive.'"

As heat and cold applied to our senses are only relative terms, it follows that nothing short of thermometrical data will serve to determine the question of change of climate. In elucidation of this point, the following table, which gives a comparative view of the temperature at Philadelphia and at Salem, Massachusetts, at intervals of many years, is presented:—

PHILADELPHIA. Lat. 39° 57′. Lon. 75° 11′.	Mean annual Temp.	Extreme range of the Thermometer.			Mean Temperature of the Seasons.			
					Winter.	*Spring.*	*Summer.*	*Autumn.*
1771, 1772, and 1775,	52.°72	90	3	87	34 °06	50. °88	71 °62	54 °32
1798, 1799, and 1800,	53. 92	96	5	91	33. 02	52. 44	75. 03	55. 21
1822, 1823, and 1824,	54. 96	96	— 7	103	32. 23	52. 11	76. 16	59. 10
1758, '9, 1767, to 1777,	52 36	91½	— 3	94½	34 07	49. 89	72. 23	54. 17
1829, to 1838,	51. 39	94	1	93	31. 43	49. 60	70. 83	53. 70
SALEM, MASS. Lat. 42° 34′. Lon. 70° 54′								
7 years from 1786 to 1793	47.°92	96	—11	107	29. 21	46. 09	69. 42	50. 31
7 " " 1793 to 1800	49. 49	99	—11	110	28. 00	47. 30	71 57	51. 10
7 " " 1800 to 1807	49. 79	99	— 3	102	29. 73	46. 71	70. 69	52. 04
7 " " 1807 to 1814	48. 22	100	— 7	107	27. 68	45. 11	68 70	51. 40
5 " " 1814 to 1819	47. 65	101	—11	112	25. 85	44. 64	68 45	51. 68
Mean of 33 years.	48 61	101	—11	112	28. 09	45. 97	69 77	51 31

The first three results at Philadelphia, which give the temperature at

intervals of about a quarter of a century, show, contrary to the opinion of Jefferson, that "both heats and colds have become moderate," that the winters have become colder and the summers hotter, while the mean annual temperature and the range of the thermometer, exhibit a successive increase. Having recently gained access to more extensive data in the Transactions of the American Philosophical Society, vol. vi., new series, the comparison has been extended. The results of the thirteen years commencing with 1758, compared with the ten years beginning with 1829, confirm the previous inference as regards diminution of winter temperature; but instead of a successive increase in the means of spring, summer, autumn, and the whole year, as by the former comparison, there is here a decrease in all. All towns are observed to grow warmer, in proportion as they extend their limits; as, for instance, London compared with its environs, gives an annual temperature of 1.°58 greater,—a law observed in all the seasons. Hence the successive increase at Philadelphia, in the first three comparisons, in the mean annual temperature and in that of spring, summer, and autumn, might be referred to its rapid growth; but when we find an undeviating decline in the mean temperature of winter, in every comparison, notwithstanding the extension of the city limits, the inference that it is due to a general diminution in the winter temperature throughout the country, seems to be warranted.

The observations made at Salem, Massachusetts,—a point free from any agency which a large town may exercise, show a most remarkable uniformity in the seasons during a period of thirty-three years. These observations, which were noted by the venerable Dr. Holyoke, have been transcribed from the original manuscript. The first four series give each a mean of seven years, and the last an average of five years. These observations, notwithstanding the rapid agricultural improvement of this region, show no permanent change of climate and very little variation in the same season. In regard to this table, it may be added that the results confirm all the laws established in the preceding pages in reference to the difference between the mean temperature of winter and summer, between winter and spring, and between the warmest and coldest month, as well as the mean annual range of the thermometer. Compared with similar latitudes remote from the agency of large bodies of water, the contrasts are very marked.

It is thus apparent that the opinion that the climate of the States bordering the Atlantic on their first settlement, resembled that now exhibited by Fort Snelling and Council Bluffs, is wholly gratuitous and unsustained by facts. No accurate thermometrical observations yet made in any part of the world, as already remarked, warrant the conclusion that the temperature of a locality undergoes changes in any ratio of progression; but conversely, as all facts tend to establish the position that climates are stable, we are led to believe that the changes or perturbations of temperature to which a locality is subject, are produced by some regular oscillations, the periods of which are to us unknown. That climates are susceptible of melioration by the extensive changes produced on the surface of the earth by the labors of man, has been pointed out already; but these effects are extremely subordinate, compared with the modification induced by the striking features of physical geography—the ocean, lakes, mountains, the opposite coasts of continents, and their prolongation and enlargement toward the poles.

But even Malte-Brun has ventured the assertion, that "France, Germany, and England, not more than twenty centuries ago, resembled Canada and Chinese Tartary—countries situated, as well as our Europe, at a mean distance between the equator and the pole." This illustration is certainly very unhappy; for, rejecting the pretended antiquity of the Chinese—the fables in relation to Fohi and Hoang-Ti, the former of whom, we are told, founded the empire of China about five thousand years ago, we must, with Malte-Brun, date its origin at least eight or nine centuries before Christ. China should, therefore, possess a milder climate than Europe, inasmuch as agriculture is represented to have been always in the most flourishing condition. As the practice of fallowing is unknown, almost the whole arable land is constantly tilled, and even the steepest mountains, cut into terraces, are brought under cultivation. Now, as this country still presents a climate as austere as that of Canada in the same latitudes, the conclusion is irresistible, that in proportion as the leading physical characters of a region are immutable in their nature, does error pervade the remark of Malte-Brun—"That vanquished nature yields its empire to man, who thus creates a country for himself."

A partial view of this question, indeed, not unfrequently leads to the most unwarranted conclusions. Any changes in the climate of the United States as yet perceived, are very far from justifying the sanguine calculations indulged in, a few years ago, by a writer* whose observations upon many other points are very valuable.

"But there will doubtless be," he says, "an amelioration in this particular, when Canada and the U. S. shall become thickly peopled and generally cultivated. In this latitude, then, like the same parallels in Europe at present, *snow and ice will become rare phenomena, and the orange, the olive, and other vegetables of the same class, now strangers to the soil, will become objects of the labor and solicitude of the agriculturist.*"

The fallacy of the opinion which ascribes the mild climate of Europe to the influence of agricultural improvement, becomes at once apparent, when it is considered that the region of Oregon, lying west of the Rocky Mountains, which continues in a state of primitive nature, has a climate even milder than that of highly cultivated Europe in similar latitudes; and again, China, situated like the United States on the eastern coast of a continent, though subjected to cultivation for several thousand years, possesses a climate as rigorous, and some assert even more so, than that of the United States proper on similar parallels.

SUBSECTION 3. IS THE CLIMATE WEST OF THE ALLEGHANIES MILDER BY 3° OF LATITUDE THAN THAT EAST?—The affirmative maintained by Volney and Jefferson, but this opinion proved to be a premature deduction, arising from the circumstance that different systems of climate are presented on the same parallel.

In regard to the region west of the Alleghanies, the opinion was early entertained that the climate is milder than that of the district east. Mr. Jefferson estimated the difference equivalent to 3° of latitude, as similar vegetable productions are found so many degrees farther north. These phenomena, M. Volney ascribed to the influence of the south-west winds, which carry the warm air of the Gulf of Mexico up the valley of the Mississippi. As North America has two mountain chains, extending from northwest to southeast, nearly parallel to the coasts, and forming almost equal angles with the meridian, Humboldt endeavored to explain the migration of vegetables toward the north, by the form and direction of this great valley which opens from the north to the south; while the Atlantic coast presents valleys of a transverse direction, which opposes great obstacles to the passage of plants from one valley to another. The tropical current or trade-wind, it is said, deflected by the Mexican elevations, enters the great basin of the Mississippi and sweeps over the extensive country lying east of the Rocky Mountains; and that when this current continues for some days, such extraordinary heat prevails even through the basin of the St. Lawrence, that the thermometer at Montreal sometimes rises to 98° of Fahr. In winter, on the contrary, when the locality of this great circuit is changed to more southern latitudes, succeeded by the cold winds which sweep across the continent from the Rocky Mountains or descend from high latitudes, this region becomes subject to all the rigors of a Siberian winter.

Upon the fallacy of these views it is deemed unnecessary to dilate. It is proved by thermometrical data that the climate west of the Alleghany is more excessive than that on the Atlantic side—a condition that would seem unfriendly to the migration of plants. Thus Jefferson Barracks, on the Mississippi, exhibits a greater contrast in the seasons than Washington city; and the same is true in regard to Fort Gibson and Fort Monroe, notwithstanding the former is 1° 32′ farther south. That the climate of the peninsula of Michigan encompassed by ocean-lakes, should prove genial to plants that will not flourish in the same latitudes in the interior of New York, is, indeed, consonant with the laws of nature; and hence the facts set forth in the following extract from a letter to Sir Humphrey Davy by Chancellor De Witt of New York, are, so far from being extraordinary, merely in conformity to the laws of climate developed in the preceding pages:—"There is evidently a considerable difference between the climates of the eastern and western parts of our state. The Cayuga and Seneca lakes are situated about 150 miles in a direct line west of Hudson's river, and each is nearly 40 miles long and from one to three and a half miles wide, both having their centres very nearly in the latitude of Albany, and yet they have hardly ever been known to be frozen over, excepting at their extreme ends, while Hudson's river never fails being frozen, commonly for two or three months in the year, for many miles to the south of Albany, not unfrequently to the distance of 100 miles, so as to bear the travelling of horses and carriages on it. While peaches and nectarines are raised here with some difficulty, they flourish nowhere better than in the western part of our State."

As the author has found the opinions of M. Volney, as well as those of Rush and Jefferson, quoted as oracular in every work professing to treat of our climate, it may not be amiss to examine this subject a little more in detail. This French philosopher had the singularly bad fortune of adopting the errors of Dr. Rush and Mr. Jefferson. For example, according to the former, as we recede from the ocean into the interior of Pennsylvania, "the heat in summer is less intense,"—a phenomenon contrary to every law of nature, unless reference was had to the Alleghany elevations; and, in accordance with the latter, the climate becomes colder as we proceed westward on the same parallel until the summit of the Alleghany is attained, when this law is reversed until we reach the Mississippi, *where it is even warmer than the same latitude on the sea-board.* This theory, by the way, is based upon the *testimony of travellers;* and "their testimony," says Jefferson, "is strengthened by the vegetables and animals which subsist and multiply there naturally, and do not on our sea-board." "As a traveller," adds Volney, "I can confirm and enlarge upon the assertion of Mr. Jefferson;" and in regard to the temperature of the regions lying east and west of the Alleghanies, he concurs in the opinion, "that there is a general and uniform difference equivalent to 3° degrees of latitude in favor of the basin of the Ohio and the Mississippi." This conclusion, which is not deduced from thermometrical data, rests, it will be observed, upon the phenomena of temperature and of vegetation exhibited in the region of the great lakes. "Even as high up as Niagara," he continues, "it is still so temperate that the cold does not continue with any severity more than two months, though this is the most elevated point of the great platform—a circumstance totally inconsistent with the law of elevations." He proceeds to say that this climate does not correspond with similar parallels in Vermont and New Hampshire, "but rather with the climate of Philadelphia, 3° farther south. * * * At Albany, no month of the year is exempt from frost, and neither peaches nor cherries will ripen." The influence of the great lakes in modifying temperature has been already so abundantly demonstrated, that further illustration is deemed supererogatory. The phenomena observed by Volney are truly facts; but the causes being unknown, the theory in regard to the difference of temperature east and west of the Alleghanies, was naturally suggested. Instead of deducing general laws from universal facts, this theory of Volney and Jefferson, as will be most conclusively demonstrated, was, however, a premature deduction—the result of hasty and partial generalization.

The difference of climate, according to Volney, is not discovered south of latitude 36°, or north of 44° or 45°, thus modifying the theory of Jefferson. "Scarcely have you passed," he says, "the south shore of Lake Erie, when the climate grows colder every minute in an astonishing degree." This remark expresses only a partial truth; for this modified temperature is found along the whole course of the great lakes, whereas proceed in any other direction, north or south, east or west, and you discover the seasons more strongly contrasted. "It is evident then," he continues, "that beyond a certain latitude the climate west of the Alleghanies is not less cold than its parallels on the east; and this latitude, the mean term of which appears to be about 44° or 45°, taking for its limits the great lakes, and more particularly the chain of the Canadian or Algonquin mountains, from this very circumstance, confines the hot climate of the western country to a space of 9° or 10°, which is surrounded on three sides by mountains."

M. Volney next enters upon an extended investigation of the system of winds in the United States; and the ignorance of this celebrated traveller in thus attempting to explain the meteorological phenomena peculiar to the region of the great lakes, shows how little was known forty

*Remarks on the Climate and Vegetation of the fortieth degree of North latitude. By Richard Sexton, M. D., in vol. 5, American Journal of the Medical Sciences.

years ago of the laws of meteorology. In reference to the Trans-Alleghany region, he thus remarks:—"I think I have clearly demonstrated that the south-west wind of the United States is nothing but the trade-wind of the tropics turned out of its direction and modified, and that consequently the air of the Western Country is the same as that of the Gulf of Mexico, and previously of the West Indies, conveyed to Kentucky. From this datum flows a natural and simple solution of the problem, which at first must have appeared perplexing, *why the temperature of the Western Country is hotter by 3° of latitude than that of the Atlantic coast*, though only separated from it by the Alleghany mountains. The reasons of this are so palpable that it would only be wearying the reader to give them. Another consequence of this datum is, that the south-west winds being the cause of a higher temperature, it will extend the sphere of this temperature so much the farther, the greater the facility with which it can pervade the country; and this affords a very favorable presage for the parts that lie in its way, and are exposed to its influence, namely those in the vicinity of Lakes Erie and Ontario, and even all the basin of the river St. Lawrence, into which the south-west wind penetrates."

Now these are the opinions still maintained at the present day, to account for the supposed fact of the higher temperature of our tramontane region. It is a good rule in philosophy to ascertain the truth of a fact before attempting its explanation,—a truism, the observance of which would have saved M. Volney the labor of constructing his complex theory of the winds. All thermometrical results confirm the law that in proportion as we recede from the ocean or inland seas, the climate grows more excessive; and that the meteorological phenomena of the region of the great lakes do not arise from the agency of tropical winds, is apparent from the single fact, that the winters are several degrees warmer, and the summers at least ten degrees cooler, as regards the mean temperature of these seasons, than positions one hundred miles distant, notwithstanding on the same parallel or even directly south, and consequently equally exposed to the current from the Gulf of Mexico. Volney's theory, in truth, bears a contradiction upon its own face; for, while he ascribes the modified climate of the lakes to the agency of tropical winds, he admits that the intermediate country traversed by these winds has a much more rigorous climate.

The influence of predominant winds is manifest, however, throughout the United States; for, one prevailing wind, the southwest, blows from a warm sea,—another, the northeast, from a frigid ocean,—and a third, the northwest, from frozen deserts.

The modification in the climate of the valley of the Mississippi, whatever may be its degree, arises from the combined agency of the Gulf of Mexico and the great lakes: for if land were substituted for the area of the latter, (93,000 square miles,) that region would become so far as the social state of man is concerned, scarcely habitable. This is well illustrated in Lyell's Geology, in which are given maps of the world, showing that change in the position of land and sea might produce the extremes of heat and cold in the climates of the globe, though having the same shape and relative dimensions as now. Upon the same principle, a partial change would induce a corresponding modification of temperature. "Let us suppose," says Lyell, "those hills of the Italian Peninsula and of Sicily, which are of comparatively modern origin, and contain many fossil shells identical with living species, to subside again into the sea, from which they have been raised, and that an extent of land of equal area and height, (varying from 1,000 to 3,000 feet, should rise up in the Arctic ocean, between Siberia and the North Pole. * * The alteration now supposed in the physical geography of the northern regions, would cause additional snow and ice to accumulate where now there is usually an open sea; and the temperature of the greater part of Europe would be somewhat lowered, so as to resemble more nearly that of corresponding latitudes of North America: or, in other words, it might be necessary to travel about 10° farther south in order to meet with the same climate that we now enjoy. No compensation would be derived from the disappearance of land in the Mediterranean countries; but the contrary, since the mean heat of the soil in those latitudes is probably far above that which would belong to the sea, by which we imagne it to be replaced."

The opinion that the climate west of the Alleghany range is milder by 3° of latitude than that east,—an opinion quoted generally by writers as an established fact,—arose from the circumstance that the United States present on the same parallel different systems of climate—causes upon which the geographical distribution of plants mainly depend.

In reference to the organic life of plants, it is well known that to some entirely different constitutions of the atmosphere are adapted. In respect to the culture of vegetables, it is necessary to keep in view three objects,—the mean temperature of the summer, that of the warmest month, and that of the coldest month; for some plants indifferent to high summer temperature, cannot endure the rigors of winter; others, slightly sensible to low temperature, require very warm but not long summers; while to others, a continuous rather than a very warm summer seems best adapted. The development of vegetation in the same mean temperature, is also retarded or accelerated, according as it is struck by the direct rays of the sun, or receives the diffuse light of a foggy atmosphere. On these causes depend in a great degree, those contrasts of vegetable life observed in islands, in the interior of continents, in plains, and on the summits of mountains. As the region of the great lakes does not exhibit a greater contrast in the opposite seasons than that of Philadelphia, it follows that plants which, from not being adapted to extremes of temperature, cannot endure the severe winter of Albany, will flourish in the mo e equalized climate of the two former regions.

Thus, as Volney and Jefferson saw that the vegetation of Philadelphia is found in the modified climate of our northern lakes, while similar plants will not flourish on the same parallels in the interior of New York, Vermont, and New Hampshire, the theory in regard to the difference of temperature, east and west of the Alleghanies, was naturally suggested. If, however, these philosophers had chanced to observe the vegetation, by way of comparison, along the coast of Rhode Island or Connecticut, and on the same parallel in Illinois or farther westward, instead of comparing the region of the lakes and Albany, the world would, *of course*, have been edified with the opposite theory, viz., that the climate east of the Alleghanies is milder by 3° of latitude than that west. While at Fort Trumbull, Connecticut, the mean winter temperature is 39°.33, at Council Bluffs it is as low as 24°.47. Hence plants sensible to a low temperature, which flourish in the climate of the former, will perish in the latter; for while the mean temperature of the coldest month at Fort Trumbull is only 34° 50, at Council Bluffs it is 22° 61. This is also demonstrated by the average annual minimum temperature, that of the former being 9°, and that of the latter —16°; and equally so by the minimum temperature of the winter months, that of December, January, and February being at Fort Trumbull respectively 20°, 10°, and 16°, and at Council Bluffs—4°,—13°, and —11°. On the other hand, it will be found that the vegetables which can endure the rigorous climate of Council Bluffs, will flourish more vigorously than in the region of Connecticut; for at the former, the vernal increase is 27°.47, and at the latter only 11°.67. Moreover, the latter increase is added to a winter temperature of 39° 33; while the former, added to 24°.47, more than doubles itself, the influence of which upon the sudden development of vegetation has been already pointed out. These relations, as developed in the tabular abstracts appended to the author's work on "The Climate of the United States, and its Endemic Influences," might be traced out much further. At Council Bluffs, the extreme of temperature in summer is also much greater than at Fort Trumbull, the mean maximum of the former being 104°, and of the latter 87°, and consequently the average annual range stands respectively as 120° to 78°. In addition to these facts, it may be observed that so far as elevation is concerned, that of the Lakes being 600 feet and that of Albany only 130 feet above the sea, the advantage of the comparison is, at first view, on the side of the latter; but this gradual elevation, it has been shown, exerts no perceptible influence.

The following extract from Murray's Encyclopædia of Geography is peculiarly in point:—

"Powerful summer heats are capable of causing trees and shrubs to endure the most trying effects of cold in the ensuing winter, as we find in innumerable instances; and *vice versâ*. Hence, in Great Britain, so many vegetables, fruit-trees in particular, for want of a sufficiently powerful sun in summer, are affected by our comparatively moderate frosts in winter; while upon continents in the same degree of latitude, the same trees arrive at the highest degree of perfection."

This examination into the opinions of Volney and Jefferson would not have been deemed necessary, did those who so freely quote their writings state the collateral fact, that much of the evidence upon which their theory is based, consists of the casual observations of travellers.

CONCLUSION.

In concluding the subject of Climatology, it is scarcely necessary to advert to the topic of the ancient climates of the earth prior to the present epoch, as this subject will be found ably treated in the following chapter by the author's friend, Charles A. Lee, M. D.

As any change in the present relation of the earth's surface would induce a corresponding alteration of climate, followed by modifications in the animal and vegetable kingdoms, the physical history of our globe proves that such changes in the distribution of heat over its surface have doubtless occurred at various periods. It is an admitted fact among geologists that the earth's surface has experienced great variations of climate since the deposition of the older sedimentary strata; but as a few thousand years are insufficient, except by a violent convulsion of nature, to affect the prominent features of physical geography, the history of man shows no well authenticated change in the general climate of any zone. It is manifest, however, that those causes are still in operation, by which regions once submerged are delivered up to man; while it is equally obvious that the sea makes rapid encroachments upon that which has for ages been his patrimony.

Of the superficies of the earth, seven-tenths are covered with water. The dry land in the northern hemisphere compared with that of the southern, according to Humboldt, stands in the ratio of three to one, and the land without the tropics as thirteen to one.* It is evident that this relation between land and water has not always existed. The presence of organic remains in rocks demonstrates that the loftiest elevations upon the surface of the globe were at some period beneath the surface of the sea. As our present continents with their most elevated mountains were formed at the bottom of the ocean, the science of geology conducts us through a vast series of submarine deposits, five or six miles in depth, abounding with the remains of plants and animals, representing not only the types of successive generations but of successively created races, each group of strata having its peculiar group of organic remains. Hence the earth's strata corresponding to the different periods of its history, may be regarded as a chronological table—a volume of history in which the strata constitute the leaves, upon which is written the climatic character of each period, as determined by the characteristics of the plants and animals which then lived and flourished. Thus we have an indication in the calcareous formations of our own country, as for example in New Jersey, that formerly the climate was much warmer than now; for these rocks are composed in great part of corals and shells, consisting both of extinct species and of genera now living in the tropical seas. As these stone-buildings zoophytes are, at the present day, mostly confined within 20° north and south of the equator, (the Bermuda Islands, at the distance of 30°, which are warmed by the Gulf-stream, being only an apparent exeception,) the opinion that northern latitudes had at some remote epoch a much warmer climate than now, is justly warranted.

During the formation of the older strata, a tropical, if not an ultra-tropical, climate prevailed over the northern hemisphere. The vegetable geology of the coal regions of Pennsylvania, for example, show that, at the period of their formation, a climate entirely different from the present, existed. Many of the fossils found are different from any plants now known, being mostly of the cryptogamous class, including arborescent ferns of gigantic growth, all peculiar to tropical, or rather ultra-tropical, regions. Vegetables pertaining to families which are now mere herbs, attained at this epoch the dimensions of the largest trees. At Wilkesbarre, Pennsylvania, fern leaves more than four feet across have been found. And in the basins of London and Paris, the fossil flora consists of palms, spice-bearing laurels, and other plants, from which the existence in those now temperate latitudes, of a tropical climate, is obviously manifested. Then, all England, save her mountain-chains, which formed a cluster of spice islands, haunted by the croco-

* The recent discovery of an Antarctic Continent modifies this relation.

dile, was yet beneath the waves; and then, on the spots where now exist her sea-ports, crowded with the flag of every nation, no sail was spread to the breeze, save that of the Nautilus of the tropics!

In regard to the coal-mines of Bohemia, the following eloquent language is used by Dr. Buckland:—"The most elaborate imitations of living foliage on the painted ceilings of Italian palaces, bear no comparison with the beautiful profusion of extinct vegetable forms with which the galleries of these instructive coal mines are overhung. The roof is covered as with a canopy of gorgeous tapestry enriched with festoons of most graceful foliage, flung in wild, irregular profusion over every portion of its surface. The effect is heightened by the contrast of the coal-black color of these vegetables, with the light ground work of the rock to which they are attached. The spectator feels transported as if by enchantment, into the forests of another world; he beholds trees of form and character, now unknown upon the surface of the earth, presented to his senses almost in the beauty and vigor of their primeval life; their scaly stems and bending brances, with their delicate apparatus of foliage, are all spread before him, little impaired by the lapse of indefinite ages, and bearing faithful records of distinct systems of vegetation, which began and terminated in times of which these relics are the infallible historians. Such are the grand natural herbaria wherein these most ancient remains of the vegetable kingdom are preserved in a state of integrity little short of their living perfection, under conditions of our planet which exist no more."

In reference to the hot climates of our northern latitudes producing the aborescent ferns, it is maintained by Lyell that mere change in the position of the land and sea of our globe, without altering their present shape and dimensions, would cause the extremes of heat and cold in climates now habitable. Hence he regards the circumstance of a preponderance of land in the equatorial regions, and of ocean toward the poles, as amply sufficient to explain the existence in northern latitudes of fossil remains, consisting mostly of genera now confined to warmer regions. In the production of these effects, other geologists, however, regard mere difference in the distribution of land and water as inadequate. These various opinions will be fully noticed in the following chapter.

Hence, in surveying the physical revolutions by which our mountains have been upheaved, thus unfolding page after page of this great book, containing the wondrous records of the changes which our globe has undergone, during a series of periods of long but unknown duration, before it was inhabited by man, the conclusion is obvious that there exists an inseparable relation between these successive groups of animal and vegetable fossil remains, each unlike all the others, found embedded at different depths, and the corresponding period of the earth's condition. As with every change in the state of the earth, we discover a corresponding change of organized bodies, we behold, as remarked in the Introduction, proofs of Supreme Intelligence not only adapting mechanism to an end, but adjusting the mechanism to the altered conditions under which it was to exist. Thus, though all things visible are subject to change, yet they are the work of one invisible and eternal Being, "the same yesterday, to-day, and forever." Aye, even man, compared with the globe upon which he dwells, is but a creature of yesterday; for human remains have not been found in or below the diluvial deposits in any part of Europe, nor have they yet been met with in the tertiary strata of any other part of the world. How many of these groups have been successively created, or how long a period elapsed between the era of the creation of our globe and that of the formation of man, we know not,—opinions which do not necessarily conflict with the Mosaic account of our race, nor with the devotional homage due to the Creator—

——"Nor think though men were none,
That Heaven would want spectators, God want praise;"

but we cannot resist the solemn conviction that we tread upon the wrecks of anterior worlds—the monuments upon which the hand of Time has engraven the history of this terraqueous globe!

CHAPTER III.

ON ANCIENT CLIMATES AS VIEWED IN THE LIGHT OF FOSSIL GEOLOGY.

BY CHARLES A LEE, M.D.

CHANGE, the order of nature.—Our northern zones, during early geological periods, had a tropical climate, as proved by animal and vegetable fossil remains.—Successive changes of organic life attended with coincident changes of physical conditions.—Our northern latitudes, at one period, had a climate like that now existing within the tropics.—Theories relative to the causes of this great climatorial change.

EVERY object, either within or upon the surface of the earth we inhabit, bears the evidence of change. It would seem that there is nothing which meets our view, that is stable and stationary; all—all are either undergoing the process of renovation or decay; waxing or waning like the beautiful orb of night, the impressive emblem of human destiny. If we dig but a short distance beneath the surface of our soil, we find ourselves ranging in the empire of a dead kingdom, where subjects bear but slight analogy to the existing orders of living nature. Anomalous and extraordinary forms, once endowed with as strange and paradoxical functions, are disclosed to our wondering vision on every side; here, an animal somewhat resembling a sloth, with enormous arms and claws for suspending itself to gigantic trees, but of the size of the elephant; there, quadrupeds, bearing wings on their toes, or crocodiles furnished with fins, but no feet; and lizards of whale-like dimensions*—all quietly reposing in their dark cemeteries, unconscious of the new creation which flourishes above them.

If we penetrate still farther, we find in every stage of our progress new proof of a different order of things, of a world, unlike our own, whose fashion has long since passed away.

That the northern zones of the earth, during early geological periods, enjoyed a climate similar to that which prevails, at the present time, between the tropics, no one can doubt who has made himself at all acquainted with the facts disclosed by fossil geology. From Melville's Island in north latitude 97°, down to the borders of Mexico, abundant remains of tropical vegetables are found in all the coal-bearing strata, and evidently reposing in, or near their native place of growth. On the northwestern coast of Baffin's Bay, and within the Arctic circle, there are immense deposites of bituminous coal, associated with shale, bearing the distinct impressions of endogenous plants, of a larger growth than any now known to exist in tropical latitudes. In all these carboniferous or coal bearing strata, we find the most delicate forms of vegetable organic structure, relics of a former age, and a warmer clime, sealed up, and retaining in wonderful perfection their pristine elegance and beauty. These remains furnish us an abundance of proof that the flora of that era, consisted almost exclusively of large vascular cryptogamic plants. It is not unusual, for example, to find among these relics, specimens of Equisetæ or Horse-tail, ten feet high, and six inches in diameter; of tree-ferns, from 40 to 50 feet in heighth; and arborescent Lycopodiaceæ from 60 to 70 feet high. "Of the above classes of vegetables," says Lyell, "the species are all small at present in cold climates; while in tropical regions there occur, together with small species, many of a much greater size; but their developement, even in the hottest parts of the globe, is now inferior to that indicated by the petrified forms of the coal formation. An elevated and a uniform temperature, and great humidity in the air, are the causes most favorable to their numerical preponderance and the great size within the torrid zone at present." After a very full investigation of the geographical extent of the ancient vegetation, Mr. Brongniart has arrived at the conclusion, that it was not confined to a small space, as to Europe, for example, or even America, for the same species are met with at great distances and in different localities. Thus the carboniferous strata of North America, furnish the same genera, as those of New Holland, Asia and Europe, and the coal plants, from Greenland and Melville's Island, are identical with those of Pennsylvania and the valley of the Mississippi, as well as those of Europe.

Can we, for a moment, suppose that the gigantic vegetation, thus disclosed, could have flourished in such an ungenial climate, as characterizes the northern latitudes at the present day, or that they could have lived through an arctic night of several months duration? We put this question because we cannot doubt that whoever sees the present dependence of animal and vegetable life on temperature moisture, soil and other characters of physical geography, cannot hesitate to believe that certain combinations of physical conditions have always been connected with every system of organic life in the successive geological periods. No true philosopher will, indeed, regard these conditions as the *cause* of those systems of life, but consider them simply as adjusted phenomena, happening in a determined order as part of a general plan. "Some changes," says Philips, "in the constitution of the globe have brought in succession various combinations of the manifold influences of those chemical and mechanical agencies which govern inanimate nature; and which appears to be the order of God's Providence, that to these combinations the powers of each newly created system of life should correspond. The several successive systems of organic life which have been discovered in the earth, were, therefore, really successive creations, and must be expected to differ, in large and general characters."—But to return to our question—Whether such a vegetation as the coal-bearing strata of the north disclose, is compatible with those conditions of heat, light, and moisture, which now characterize the same latitudes. Were this the case, we should doubtless find the same vegetation or one of similar luxuriance, abounding in the same region; but instead of this we meet with only a few stinted willows, larches, firs, &c., with an abundance of lichens, fungi, and mosses.

Assuming that the extreme northern point to which a flora like that of the carboniferous era could reach, is somewhere between the latitudes of 65° and 90°, Mr. Lyell has asked, whether the vegetable remains might not have been drifted from thence, by rivers and currents, to the parallel of Melville Island, or still further. It is true that at the present day, we see the materials for future beds of lignite and coal becoming amassed in high latitudes at a considerable distance from the place where the forests grew, and the Mackenzie and other rivers which empty into the Arctic Sea, carry along pines and other drift wood, many hundred miles into the northern ocean, where they are imbedded in deltas, or wafted towards the pole. There are two objections to this supposition, either of which ought to suffice to show that it is unsatisfactory. In the first place, the preservation of the plants themselves, retaining the distinct outline of the stems and leaves, with many delicate lines and streaks; the leaves themselves being attached to their branches, show very conclusively, that they could not have been drifted to any great distance, or remained long immersed in water. In the next place, as we have already remarked, the plants either belong to extinct genera, or are different from those now found in similar latitudes. Though we need more precise information in relation to the fossils of the coal-bearing strata of high latitudes, yet we have sufficient to justify us in the conclusion, that at a former geological period, how remote no one can tell, the northern portion of our globe enjoyed a far higher temperature than it does at the present time.

Further proof of the same fact is found in examining the fossil remains of living species of marine animals, and comparing them with those inhabiting our present seas and oceans. This comparison, as Mr. Lyell well remarks, furnishes an accurate test, and enables us to subject a theory of climate to the experimentum crucis. The same geologist found that in Sicily, Ischia, and Calabria, where the fossil testacea of the more recent strata belong almost entirely to species now inhabiting the Mediterranean, the individuals in the inland deposits often exceed in their average size their living analoguos, showing that the circumstances under which they lived were more favorable to their developement; and that they were identically the same species, is proved by the fact that living individuals precisely similar, still are met with, in warmer latitudes attaining the average size of the fossils. Lyell found, that out of several hundred different species of shells which he collected in Sicily, from 1000 to 3000 feet above the level of the sea, nearly all were identical with species now inhabiting the Neapolitan seas; and moreover, that the relative abundance in which different species occur in the strata and in the sea, corresponds in a remarkable manner. In

* The remains of a Saurian or fossil lizard, dug from the earth about six feet beneath the surface in Alabama, are now in this city. This extinct monster measures 70 feet in length!

general, however, the fossil species were much larger than the living, showing a higher temperature of the water they inhabited. As we go north, we find that although the fossil shells depart somewhat more widely from the type of the neighboring seas, that still many are identical with species now living in the Mediterranean—though the number no longer predominates. Shells gathered from the Sub-Appenine hills, although several degrees farther from the equator, still bear the indications of a hotter climate. The fossil species and their analogues from tropical seas, correspond in size, while the same species from the Mediterranean are diminutive and stunted in their growth, evidently from the want of those conditions found in tropical seas. That this proof is of a very satisfactory character there can be no doubt whatever, and as Mr. Lyell remarks, cannot be neutralized by any fact of conflicting character. Suppose, for example, that the fossil species, from the coal-formation of Melville Island, have their living analogues; we are to seek for them, not in the northern ocean, nor in the seas of the temperate latitudes, but between the tropics. Further, the fossils of the tertiary basins of Paris and London, indicate a warmer climate than those of Bordeaux, or the more modern strata of Sicily, although several degrees further north, while those of Bordeaux afford satisfactory evidence that they lived in hotter seas, than those of Sicily, seven degrees nearer the equator. These facts, and numerous others of a like kind, all point to a gradual refrigeration of climate.

In addition to all this, it is a well known fact, that the limestone rocks, on which the carboniferous strata of northern latitudes repose, are themselves, composed of fossil corals and corallines, whose prototypes are at present met with only in the warm seas of tropical regions, showing conclusively, that even before the deposition of the coal formation, the waters of the polar ocean were adapted to the same forms of animal life as now inhabit the equatorial seas. Another fact, pointing to the same conclusion, relative to the former condition of the climate of our earth, is the remains of extinct species of land quadrupeds, such as the elephant, rhinoceros, hippopotamus, hyena, lion, tiger, and other genera now chiefly confined to warmer regions, among the superficial deposits of sand, gravel, and loam, scattered over various parts of Europe, Asia, and America. Especially the immense quantities of the bones of fossil elephants in northern Siberia, which have no marks of having been transported to a distance, attest the existence on its plains of these herbiverous animals at that remote period; thus demonstrating the existence of a once flourishing vegetation in a country which now scarcely furnishes sufficient moss to supply the wants of a few half famished reindeer.

Pallas and other writers represent the bones of the mammoth as abounding throughout all the lowland of Siberia, extending from the borders of Europe to Behring's Straits, and from the base of the mountains of Central Asia to the shores of the Artcic Sea. Over this whole region occupying a space nearly as large as the whole of Europe, fossil ivory has been found, particularly on the banks of the rivers, where they present lofty precipicies of sand and clay. They are sometimes found imbeded in sand and gravel with marine remains, or mixed with fossilized wood, derived from carbonized peat. On the banks of the Yeni-Sey, in latitude 56°, Pallas found the tusks and bones of elephants in strata of yellow and red loam, with alternate deposites of coarse sand and gravel, containing the petrified wood of the willow and other trees, with layers of black coal. Still further to the north, in latitude 70° as well as in numerous other places, he found the same bones mixed with marine petriactions, such as sea-shells, and fishes teeth. In 1772 an entire carcass of a mammoth was discovered by Pallas on the banks of the Wiljuri, one of the tributaries of the Lena, covered with sand, where it must have remained congealed for ages. Another entire carcass of a mammoth was found by Mr. Adams in 1803, much farther to the north, in latitude 70°, on the banks of the Lena. This skeleton is now in the museum of St. Petersburgh, and portions of the hair or bristles are to be seen in the collections of the Lyceum of Natural History of New York. This individual was 9 feet high and 16 feet long, without reckoning the large curved tusks, which is about the size of the largest living male elephants. So abundant are the fossil remains of the mammoth throughout Northern Russia, that it is computed by travellers that the bones still left in that region greatly exceeds in number all the elephants now living on the face of the globe.

From the facts connected with the distribution of these fossil remains, Mr. Lyell draws the conclusion that a large region in Central Asia, including perhaps the southern half of Siberia, enjoyed, at no very remote period in the Earth's history, a temperate climate, sufficiently mild to afford food for large herds of elephants and rhinoceroses, of species distinct from those now living. If we suppose that a vegetation capable of nourishing these great quadrupeds are furnished between the latitudes of 40 and 60°, resembling that of England, we may account perhaps satisfactorily for the remains of these animals imbedded in the banks of the rivers, as they all flow from south to north, the Yenesei being 2500, and the Lena 2000 miles in length. That the present vegetation between these latitudes, to say nothing of the extreme cold of the winter months, is not adapted to the existence of these animals, is too evident to need remark. As to the causes of their extermination it is perhaps useless in the present state of our knowledge to speculate. That it has been brought about by changes in the physical geography of the Arctic region, causing a gradual refrigeration of climate, as maintained by Mr. Lyell, we are hardly prepared to believe; and yet that it may have been connected with climatorial changes produced by other causes, we think highly probable, if not absolutely certain. There is, however, but little reason to suppose that these animals, together with their companions, the rhinoceros, hippopotamus, and tapir, were overwhelmed by some sudden catastrophe, accompanied by an equally sudden change of climate, for we know of no cause, adequate to the production of such a catastrophe, at all reconcilable with the facts in the case.

Besides the remains of fossil plants, of moluscous animals, and of gigantic quadrupeds, which are found in northern latitudes, and which testify to the existence of a former higher temperature in those regions, we might also speak of the fossil relics of the crocodile, the turtle, and tortoise, together with large shells of the genus nautilus, also testifying to the same fact. Of the numerous organized fossils entombed in the secondary rocks forming a vast portion of the North American continent, including the whole valley of the Mississippi, extending from the Alleghanies to the Rocky Mountains, and from the Gulf of Mexico to the northern lakes, if not to the Arctic Ocean, nearly all are of unknown species, and yet many are referable to genera and families now most abundant between the tropics. Of these we need only allude to the most remarkable, such as the Megalosaurus and other gigantic reptiles, some of them herbiverous, others carniverous, and far exceeding any now existing on the surface of the globe. Though the genera are for the most part extinct, yet the crocodile and monitor, which inhabit the rivers and lakes of tropical climes, may still be considered their types or representatives. When we consider in addition to all this, that these secondary formations, even as far north as Baffin's Bay and Melville Island, are composed in a great measure of fossil corals, the work of *polyparia*, which only inhabit equatorial seas, we shall need no further evidence that the former temperature of the higher latitudes on our globe was much greater than at present. Indeed this is now admitted among the established inferences of geology, as deduced from the evidence already given, though there is by no means a like unanimity of opinion with respect to the *causes* which have brought about so great a change. In maintaining such a doctrine, however, we by no means deny that other causes beside climate, limit the distribution of animal life. To show the absurdity of such an opinion, we have only to examine the animal and vegetable productions of New Holland and compare them with those of other countries situated in the same latitudes. It would be scarcely an exaggeration to say, that its quadrupeds, its birds, its insects, and even its vegetable productions are all new, the latter of but little use, and producing no esculent fruits,—although enjoying similar conditions of heat and moisture, with some of the most productive regions of the globe.* When we survey the gigantic *tree-ferns*, the *Cycadreæ Araucariæ, Casuarinæ, and Orchideæ* of Australia; its *corals* and *sponges*; its *trigoniæ cerithium* and *isocardia*; its *quadrupeds* of the marsupial races similar to those of the Stonesfield slate, and other remarkable peculiarities which might be mentioned, we cannot at least avoid a suspicion that the anomalous productions of that region bear a striking resemblance to the primeval fauna and flora. But it requires no labored argument to prove, that such animals and vegetables require for their growth, far different conditions, as respects heat and moisture, than those which now prevail in high latitudes—though the fact itself is extremely curious, and should lead the geologist to examine further analogies of a similar kind, as calculated to furnish important data for ascertaining the physical conditions of the globe. In the foregoing remarks, we have assumed the dependence of animal and vegetable life on climate, soil, and other characters of physical geography, believing that it will be conceded, that to every system of organic life, in every geological period, certain combinations of physical conditions necessarily belong. Such a belief does not require us to suppose that the creation of new, must always be accompanied by the destruction of *all* the old forms, since the constitution of different races, is doubtless equally adjusted to external circumstances. We see this fact illustrated in the existence of many species of molluscous animals, especially of the *conchifera* and *cephalopoda* during the deposition of all the great ranges of strata, from the primary down to the latest tertiary, even to the present day. Thus the *Terebratula* and the *Nautilus*, are found in every system of strata, and still abound. The *producta* flourished during the transition and carboniferous eras, but perished in the saliferous period: the *spirifera* was a cotemporary with the last, passing through the same periods, but ending in the oolitic: while the *gasteropoda*, and other generæ, which came into existence during the tertiary period, still flourish, many perhaps, in equal abundance, in the waters of tropical seas. The same is true of *articulated* animals, *fishes*, *reptiles*, and various species of *pachydermata* and *ruminantia*: and it is curious to observe, how, as we rise in the scale of organization, they become more sensibly dependent on physical conditions. If we go back in imagination to the *age of reptiles*, which was during the deposition of the oolitic and lias strata, we find that the rivers, the shores, and the land, abounded with *Saurians* of gigantic size, analogous to the crocodile, lizard, and turtle, and that, too, in latitudes far distant from tropical climes. It is true we find a different organization, as for example in the *plesiosaurus*, and the *iguanadon*, and those still more wonderful animals, the *pterodactylus*, uniting the wings of a bat with the skeleton of a lizard, and the *Ichthoysaurus*, combining the form of the dolphin with the teeth of the crocodile, the paddles of the turtle, the vertebræ of a fish, and the eyes of a bird. To this succeeded another era, when these monsters, having perished from the earth, and been entombed in their dark and silent cemeteries, the race of *Mammalia* was called into being, and which still flourish, the lords of the existing order of beings. Passing, then, the whole fossil creation in review, and finding that those of the transition, the secondary, and the tertiary, all differ from each other by large and general characters, can any one doubt that the successive changes of organic life, were attended with coincident changes of physical conditions, and that both operated over very large portions of the globe, though in unequal degrees and under different circumstances

The conclusion to which we have now arrived, namely, that the climate of the Northern Hemisphere, once enjoyed a mean annual temperature similar to that now experienced within the tropics, was also that of the earliest naturalists who investigated the contents of the ancient strata. Since that period, so many new facts have been discovered, and such an abundance of testimony accumulated, that, at present, whoever should maintain a contrary opinion, would be considered as totally unacquainted with the science of geology, or sceptical as to

* "It is New Holland," says Mr. Field, "where it is summer with us when it is winter in Europe, and *vice versa*; where the barometer rises before bad weather, and falls before good; where the north is the hot wind and the south the cold; where the humblest house is fitted up with cedar; where the fields are fenced with mahogany, and myrtle trees are burnt for fuel; where the swans are black and the eagles are white; where the kangaroo is an animal between a squirrel and a deer, has five claws on its fore paws and three talons on its hind-legs like a bird, and yet hops on its tail; where the mole lays eggs yet suckles its young, and has a duck's bill; where there is a bird with a broom in its mouth instead of a tongue; where there is a fish one half belonging to the genus *Raia* and the other to that of *Squalus*; where the pears are made of wood, with the stalk at the broader end; and where the cherry grows with the stone on the outside."

the facts, which it has thus far revealed. With regard to the *causes* of this great climatorial change, there is, unfortunately, a greater difference of opinion, as there are more inherent difficulties connected with the subject. We shall notice a few of them with our objections, and then proceed to state that which seems most satisfactory to us, and which can be reconciled with the greatest number of facts, together with our reasons for its adoption. The first theory which was proposed, was, that the earth's axis had been for ages perpendicular to the plane of the ecliptic, so that there was a perpetual equinox and uniformity of seasons throughout the year; and that this continued until the time of Noah's flood, or perchance till the day when Joshua commanded the sun to stand still, when the earth by some sudden shock lost its equipoise, its axis became inclined or oblique, inducing the varied seasons, together with the long days and nights of the polar circles. This theory enjoyed but a temporary popularity, for as soon as the principles and laws of astronomical science were applied to its investigation it was found to be utterly untenable, and at the present day it has consequently no advocates.

Again, it has been supposed that the changes in the earth's climate have been occasioned by an increase or diminution of the calorific influence of the sun, caused by variations in the mean distance of the earth from that luminary. Sir John Herschel has investigated this subject with great ability, and the following are the conclusions at which he has arrived: The major axis of the earth's orbit is invariable, but the minor axis is subject to considerable change in a long period of time, though the limits of the variation of eccentricity which this produces in the earth's orbit are as yet unascertained. This eccentricity is at present, and has been for ages beyond the reach of history on the decrease, because the minor axis of the earth's elliptic orbit is continually lengthening. The limit of this elongation is now nearly reached, for the orbit has become nearly circular. Now as the amount of solar heat received on the surface of the earth diminishes as the minor axis is elongated, he earth's heat derived from the sun has been through all historic time, and is yet on the decrease. The quantity of solar heat received on the earth, is, in fact, inversely proportional to the length of the minor axis of the orbit, and were the limits of the variation of this axis calculated the extreme change of climate from this cause might be known. Taking, however, the extreme measures of eccentricity, which occur in our planetary system (Juno and Pallas, for example) as possible in the case of the earth, it follows from calculation, that the utmost difference of mean solar radiation might amount to about 3 per cent, a quantity altogether inadequate to account for the changes of climates established by geological observations. The solar heat annually poured upon the earth is computed by Pouillet to be sufficient to melt a coat of ice fourteen inches thick incrusting the whole globe of the earth.* (Philips.)

There has been considerable effort made, of late, to ascertain the heat of the planetary spaces; for if it be not the same in every part, and if the whole solar system has a consentaneous movement in space, it is very possible that at some former period the earth may have passed through regions of the universe which communicated heat, instead of abstracting it. MM. Fourier and Swanbergh, by a different line of reasoning, have arrived at the conclusion that the temperature in these spaces is about 50° centegrade (or — 36° Fahr.) below the freezing point, while M. Poisson admitting this to be the fact, as well as the existence of great heat in the central parts of the earth, assigns the following reason for the exalted temperature below the surface:—"The cosmical regions in which the solar system moves have a proper temperature of their own, and this temperature may be different in different parts of the universe. The earth, in whatever part of these spaces it be placed, must be some time in acquiring the temperature of that region, and this temperature will be propagated gradually from the surface to the interior parts. Hence, if the solar system moves out of a hotter into a colder region of space, the part of the earth below the surface will exhibit traces of that higher temperature, which it had before acquired. Thus, without supposing great heat in the whole mass of the interior parts of the earth, the phenomenon of augmenting temperature below the surface would be explained." As this can only be regarded as an ingenious speculation, sufficient doubtless to explain the phenomenon, could we but be assured of the truth of the premises, which necessarily are based on assumption, we shall pass it by without further comment.

Professor Ure, of Glasgow, has proposed another theory, no less untenable, and far less philosophical. He supposes that previous to the deluge, the Antediluvian area had a less superficial aid than ours, and consequently a greater depth. Assuming that they would bear the ratio to each other in surface as to 2 to 3, and in depth as 3 to 2, thus causing the Antediluvian ocean to penetrate one half further into the crust of the earth than it does at present, and then, moreover, assuming that in the age immediately anterior to the deluge volcanic fires were constantly active, and raging with an intensity of which there are at present no examples, throwing up all those volcanic, plutonic, and metamorphic rocks which now exist upon our globe, be inferred that the entire oceanic waters would thus be heated, to that degree, as not only to be adapted to the existence of polyparies and shell-fish; but that sufficient heat would thus be propagated to the solid land, as to furnish that high temperature, essential to that luxuriant vegetation, disclosed by the coal-bearing strata.*

A theory, based on so many assumptions, and those too of so improbable a character, hardly deserves a serious consideration. Could it be satisfactorily shown, that between the creation of man and the deluge, all the plutonic and volcanic, to say nothing of the metamorphic rocks were upheaved from the bowels of the earth, indicating an infinitely more vast and violent degree of volcanic agency, than has been experienced within the historic period, we might then begin to speculate, whether such a state of things, or the causes which produced them, would be adequate to explain the phenomena in question. It would seem very remarkable, if the antediluvian earth had been the scene of such violent catastrophies, and overwhelming eruptions, that the sacred historian, Moses, has made no allusion whatever to these wonderful events, the only phenomena of a like character, which he has related being the destruction of "Sodom and Gomorroh, and the cities of the plain "by a volcanic eruption, figuratively described as "fire from heaven." But waving all other objections, it is enough to know, as we assuredly do, that between the creation of man and the deluge of Noah, there was not sufficient time for the deposition of those immense secondary strata, composed almost entirely of the fossil shells of extinct genera of marine animals, which have been cut through and upheaved, by basaltic and volcanic rocks protruded from below. We therefore dismiss this theory as equally unsatisfactory as the former.

We next come to the highly ingenious theory of Mr. Lyell, who attributes the changes of climate in different geological periods, the changes of position of the land—in other words, to former fluctuations in the physical geography of the earth. "If doubts and obscurities" says Mr. L. "still remain, they should be ascribed to our limited acquaintance with the laws of nature, not to revolutions in her economy;—they should stimulate us to farther research, not tempt us to indulge our fancies in forming imaginary systems for the government of infant worlds."

In order to appreciate properly the influence of physical geography, upon climate, it will be necessary to advert to a few facts of a prominent nature, connected with this subject, and then we shall be prepared to judge of the sufficiency of this cause for the production of the phenomena in question. It is well known that zones of equal warmth both in the atmosphere and the sea, are neither parrallel to the equator, nor to each other. Places in the same latitudes in Europe and America, have sometimes a mean difference of temperature amounting to 11°, and even in some cases to 17° Fahr.; and some places on the two continents enjoying the same mean temperature differ from 7° to 13°, in latitude. Thus Upsal, in latitude 60° N. has about the same mean temperature, (42°) as Quebec, in lat. 47°. The isothermal line of 32° crosses the North Cape in lat. 70°, and from this vertex of curvature descends south-ward by the south side of Iceland, and the south part of Greenland, to the north points of Labrador, almost to lat. 60°; the curve then bends to the north, and reaches 65° at Great Bear Lake, beyond which its course has not been traced. In the other direction from the North Cape, this line deviates to the south till it crosses the Lena, below lat. 65°. Thus on the line of 32° it rises in the meridian of Norway 14° of lat. farther north than in America, and 5° farther north than in Asia. Nearly similar results would follow from tracing the other isothermal lines determined by Humboldt in high northern latitudes; but for a very full and satisfactory statement of facts on these subjects, we may refer to Dr. Forry's excellent treatise of which this forms the sequel. It is therefore, deemed unnecessary to repeat what has been already so ably said in the preceding pages relative to the laws which govern the superficial temperature of the earth, producing the most remarkable contrasts on the same parallels, for example in the European climate and in that of eastern North America, as well as in the northern and southern hemispheres. The conclusion then to which Mr. Lyell arrives from all the facts and principles connected with the laws of temperature, is, that wherever a greater extent of high land is collected in the polar regions, the cold will augment; and the same result will be produced when there is more sea between, or near the tropics; while on the contrary, so often as the above conditions are reversed, the heat will be greater; in other words, we shall have the *greatest uniformity* of climate, with the greatest expansion of sea; the *greatest mean annual heat* toward the poles, with equatorial land and polar oceans; and the *least mean annual heat* with polar land and broad equatorial seas. (Philips.)

As to the constant variation and alternation of land and water, there are facts enough to place the matter beyond all doubt, and yet we have no sufficient data to warrant us in the belief that there has actually existed at any former period, precisely *such* a distribution as the theory of Mr. Lyell requires. Such an arrangement indeed involves no physical impossibilities, or even improbabilities, and yet it must be regarded as purely hypothetical, for the want of facts bearing immediately upon the point in question. But granting the existence, at a former geological period, of such an arrangement of land and water, it still remains to be determined whether such arrangement would be sufficient to explain the facts admitted concerning ancient climate. Mr. Philips has well remarked, that if we take the oceanic polyparia which abound in reefs among primary and carboniferous strata, as a mark of climate not inferior to that of the coolest regions where now coral reefs are formed, the mean temperature of the sea in the latitude of Christiana, situated on what is now *the warmest band passing across the isothermal lines*, (now about 43°,) must have been about 20° Fahr. higher, which, added to the already existing excess of temperature on this line above the average, makes nearly 30° Fahr. for the necessary augmentation of *marine* temperature toward the north pole. It is necessary also to suppose a similar augmentation of temperature upon land, for the vegetation of coal strata, such as arborescent ferns, lepidodendra, sigillaria, and calamites, as well as the fluviatile reptilia, demand a uniform temperature above 60° Fahr.; and it has been calculated that the mean temperature of the land which supplied the plants now buried in the coal-field of Edin-

* It was known to Sir Isaac Newton that the obliquity of the ecliptic was in a state of diminution, and about 2-5ths of a degree less than in the time of Aristotle; but he lacked the necessary data, especially the preparatory steps, and improved mathematical methods, by which the stability or instability of the solar system could be established. It required the labors of all the astronomers of Europe from the time of Newton to Lagrange and Laplace, to enable the latter to demonstrate the stability of the solar system, to prove that in the long run the orbits and motions remain unchanged, and that the changes in the orbits, which take place in shorter periods, never transgress certain very moderate limits. "The planets," says Whewell, "produce perpetual perturbations in each others motions, but these perturbations are not indefinitely progressive—they are periodical; they reach a maximum value and then diminish. Each orbit undergoes deviations on this side, and on that of its average state; but these deviations are never very great, and it finally recovers from them so that the average is preserved. The periods which this restoration requires are, for the most part, enormous; not less than thousands, and in some instances, millions of years; and hence it is that some of these apparent derangements have been going on in the same direction since the beginning of the history of the world. But the restoration is in the sequal as complete as the derangement; and in the meantime the disturbance never attains a sufficient amount seriously to alter the adaptations of the system." (*Laplace Expos. du Syst. du Monde*, p. 441.)

* "The circulation of a body of waters thus rendered tepid by subjacent heat," says Ure, "was the most direct method of diffusing a genial soft climate over all the contiguous lands. The efficiency of this process will be readily appreciated by the modern horticulturist, who has learned to heat his vineries, &c., with economy and precision, by circulating hot water in a series of iron pipes distributed through them."—Ure's Geol. p. 490.

burgh, was at least 15° hotter than now occurs on this warm meridional band.

We think it very evident, then, that no disposition could be made of land and water, so as to insure a degree of warmth equal to that which would be required for the production of the fauna and flora already described. We agree, therefore, with Mr. Philips, that in general it is unsafe to push the possible *average* change of temperature in extra-tropical regions, beyond the *extremes* now observed therein. "America," he remarks, "with little north tropical and wide north polar land, gives us a case of extreme refrigeration from the pole toward the equator; Africa and the west of Europe compose a surface of wide and hot north tropical land, with free channels to a polar sea. The extreme difference of these extreme climates does not we believe in any two points of like elevation reach 20°; the half of which, is, perhaps, more than the extreme excess or defect of heat beyond the average of the latitude at any one point upon the surface of the earth." This writer very rationally concludes that if an *average* excess of 10° of temperature be allowable according to this hypothesis, the *extreme* excesses may have been somewhat greater; but from the conditions of the hypothesis, they cannot be taken to be so great as the extreme excesses now observed on the globe, but must be supposed comparatively small.

There remains then but one more theory by which we may reconcile the ancient physical conditions of our globe, with those animal and vegetable remains, which fossil geology has revealed to our sight. We mean the gradual refrigeration of our globe, from a once fluid, incandescent mass. The principal facts connected with the internal heat of the earth, according to Kane, are the following. Though at the surface, the temperature of the earth is solely dependent upon the radiating power of the sun, yet it is found that it contains within itself a source of heat, which in ages excessively remote, must have retained the general mass of all the constituents of the mineral globe in igneous liquefaction. At 40 feet below the surface we arrive at a layer, of which the temperature is in winter and in summer exactly the same. On descending below this depth, the temperature gradually increases, and although subject to irregularities consequent on the different conducting powers of the rocks of different countries, the augmentation is in general about one degree for every 42 feet, or about 120° for every mile. At a depth of two miles, therefore, water would not exist as a liquid—at four miles depth, tin and bismuth would naturally be liquid—and at five miles, lead. a depth of 30 miles the temperature would be so high as to melt iron; At and still more easily, almost without exception, the rocks which constitute the solid earth which we inhabit. This central mass is, therefore, doubtless, in a violent state of activity at a short distance beneath the surface; so that we live upon a pelicle of solid crystalline rocks, with which the melted mass has become skinned over, and which extends but to 1-140 of the distance to the centre. Hence we can well imagine, that in many places, where orifices or cracks in this solid crust might form, violent manifestations of the internal fire should be produced, and the magnificent phenomena of volcanoes and earthquakes, should thus arise.—(*Kane Cham. p.* 106.)

Fourier has demonstrated mathematically that though the earth be in an incandescent state at a distance of 12 to 18 miles from the surface, yet that the effect of this fervid mass upon the temperature at the surface may be scarcely a perceptible fraction of a degree. "We know certainly," says he, "from theory and observation, that the effect of this internal heat has long since become insensible on the surface, even though it may be very great at a moderate depth. The access of temperature, which the surface of the earth now possesses, in consequence of this internal source, is probably below the 15th part of a degree of Fahrenheit's thermometer. If the earth below 12 leagues depth were replaced by a globe of a temperature 500 times greater than that of boiling water, 200,000 years would be required to increase the surface of the earth 1°. The course of ages will bring about great changes in the internal temperature; but at the surface these changes have been completed; and the continual loss of the internal heat cannot hereafter occasion any refrigeration of climate. Since the time of the Greek school at Alexandria, the temperature at the surface, has not diminished, from this cause, the 150th part of a degree,—for had this been the case, some change in the length of the day would have become perceptible." It requires no argument then to prove, that in early geological periods, the influence of the interior heat was far greater than at present upon the surface of our globe, sufficient indeed to furnish the exact temperature for the production of coral reefs in the sea, palms and tree ferns upon the land, and saurian reptiles, in the rivers, lakes, and estuaries. We trace the evidence of this heat in all the geological changes, in the shape and density of the earth, the temperature of the surface and interior parts; the general floor of igneous rocks beneath the surface; the upheaving of these rocks, fractures of the earth's crust, volcanic eruptions, earthquakes, &c. It is the only hypothesis which combines in its explanation, so many of the prominent facts and principles of geology. Indeed, there is hardly a single geological phenomenon,—whether it be the earlier or later deposites of water; the induration of the ancient rocks; their freedom from organic remains; the changes of climate; or the periods of ordinary and critical action; but what may be rationally accounted for upon this one single principle. And there is no other single principle on which they can be explained. To elucidate this hypothesis in all its bearings, would require a greater amount of time and space, than we can at present command; we must therefore content ourselves with the bare statement of it, and the expression of our confident belief, that a sufficient number of facts have already been accumulated, to entitle it to the character of an established general theory.

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